



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification 5 :</b> A61K 39/00, G01N 33/53 C12N 9/96, C07K 15/14 C12N 1/00		A1	<b>(11) International Publication Number:</b> WO 90/05537 <b>(43) International Publication Date:</b> 31 May 1990 (31.05.90)
<b>(21) International Application Number:</b> PCT/US89/04864 <b>(22) International Filing Date:</b> 1 November 1989 (01.11.89)  <b>(30) Priority data:</b> 271,863 16 November 1988 (16.11.88) US		<b>(81) Designated States:</b> AT (European patent), AU, BE (European patent), CH (European patent), DE (European patent), DK, FI, FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), NO, SE (European patent).  <b>Published</b> <i>With international search report.</i>	
<b>(71) Applicant:</b> BRIGHAM AND WOMEN'S HOSPITAL [US/US]; 75 Francis Street, Boston, MA 02115 (US). <b>(72) Inventors:</b> SILBERSTEIN, David, S. ; 42 Hill Crest Road, Medfield, MA 02052 (US). MINKOFF, Majorie ; 26 Hemenway Street, Apartment No. 11, Boston, MA 02115 (US). <b>(74) Agents:</b> GOLDSTEIN, Jorge, A. et al.; Saidman, Sterne, Kessler & Goldstein, 1225 Connecticut Avenue, N.W., Suite 300, Washington, DC 20036 (US).			

**(54) Title:** INHIB, A FACTOR WHICH INHIBITS CYTOKINE-ACTIVATED LEUKOCYTES

**(57) Abstract**

The present invention relates to a molecule (INHIB) which inhibits leukocyte immunological activity, processes for preparing and purifying the molecule, a screening assay, compositions containing INHIB, and diagnostic and therapeutic uses of the molecule.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	ES	Spain	MG	Madagascar
AU	Australia	FI	Finland	ML	Mali
BB	Barbados	FR	France	MR	Mauritania
BE	Belgium	GA	Gabon	MW	Malawi
BF	Burkina Fasso	GB	United Kingdom	NL	Netherlands
BG	Bulgaria	HU	Hungary	NO	Norway
BJ	Benin	IT	Italy	RO	Romania
BR	Brazil	JP	Japan	SD	Sudan
CA	Canada	KP	Democratic People's Republic of Korea	SE	Sweden
CF	Central African Republic	KR	Republic of Korea	SN	Senegal
CG	Congo	LI	Liechtenstein	SU	Soviet Union
CH	Switzerland	LK	Sri Lanka	TD	Chad
CM	Cameroon	LU	Luxembourg	TG	Togo
DE	Germany, Federal Republic of Denmark	MC	Monaco	US	United States of America

- 1 -

TITLE OF THE INVENTION

**INHIB, A FACTOR WHICH INHIBITS  
CYTOKINE-ACTIVATED LEUKOCYTES**

BACKGROUND OF THE INVENTION

This invention was made in part with Government support. The Government has certain rights in this invention.

Field of the Invention

The present invention relates to the identification and substantial purification of a factor (INHIB) that inhibits the immunologic activity of cytokine-stimulated leukocytes. The invention additionally relates to processes for preparing the INHIB molecule, methods of purifying the molecule, screening assays for the molecule, compositions containing INHIB, and uses for the molecule.

Description of the Related Art

Levels of circulating leukocytes are elevated in conditions such as allergy, asthma, parasitic diseases, autoimmune disorders such as connective tissue disease, in certain types of cancer, and in patients undergoing therapy with interleukin-2 (IL-2) or granulocyte-macrophage colony-stimulating factor. Leukocytes, in particular eosinophils, persist in the circulation with a half-life of several hours

-2-

to two days and then either enter the marginated (blood vessel wall) pool or infiltrate tissues. At the site of inflammation in tissue, eosinophils and neutrophils, for example, secrete toxic substances that may kill infectious organisms but also may damage host (patient) tissues. For example, in the condition known as idiopathic hypereosinophilic syndrome, eosinophil cytotoxins cause ultrastructural damage and progressive fibrosis in the major organ systems, and ultimately lead to death due to cardiac or respiratory arrest, or liver failure.

Current treatment of leukocyte-mediated inflammatory disease consists of administering a variety of anti-inflammatory, antiproliferative, or cytotoxic drugs including prednisone, vincristine, and hydroxyurea. The efficacy of these drugs varies, depending on the disease state but there is no good treatment for idiopathic hypereosinophilic syndrome, for example. All of the drugs currently used therapeutically can have severe side effects on the subject. Similarly, there is an absence of effective drug treatments for many types of inflammatory diseases (such as rheumatoid arthritis) which involve inflammatory cells other than eosinophils.

Several research groups have identified substances from biological sources that have inhibitory activity in vitro in assays that may correlate with processes in inflammation (processes that do not involve eosinophil function). These purified substances presumably may have some efficacy in the treatment of inflammatory disease; for example, uromodulin (Muchmore et al., Science 229:479 (1985), J. Biol. Chem. 259:13404 (1984), and 263:5418 (1988)), and undefined activities that protect L929 tumor cells from the toxic effects of tumor necrosis factor (TNF) (Seckinger et al., J. Exp. Med. 167:1511 (1988) and Lin et al., Immunology 63:663

(1988)). Uromodulin, for example, binds with high affinity to interleukin-1 (IL-1) and to TNF, suggesting that its activity is specific for cellular events mediated by these two factors.

It is also possible that the processing of biological fluids may produce substances with apparent anti-inflammatory activities (Justement *et al.*, *J. Nat. Cancer Inst.* 73:469. This group showed that chromatography of low density and very low density lipoproteins can oxidize the lipid moieties of these molecules, producing a molecule that inhibits monocyte cytotoxic function.

Abundant evidence demonstrates that eosinophil cytotoxic function can be enhanced by a number of immunological mediators, but there was no previous evidence of a mechanism to suppress this function.

Current treatment modalities for inflammatory disease are very unsatisfactory. Any means capable of attenuating or inhibiting cellular mechanisms of inflammation would, therefore, be highly desirable for subjects suffering from certain inflammatory disease processes.

#### SUMMARY OF THE INVENTION

The inventors have now discovered, and this invention relates to, a factor which inhibits the immunological activity of cytokine-stimulated leukocytes, in particular eosinophils and neutrophils. This factor, called INHIB, which suppresses proinflammatory functions, may be found in sera and various other biological tissues and fluids. This factor consists of a single polypeptide species and has a molecular weight (MW) of approximately 70 kilodaltons. Its activity is destroyed by either heating at 80°C or by treatment with trypsin, demonstrating that it is a polypeptide.

The inventors discovered, during the course of molecular sizing HPLC, that the potency of INHIB increased. When serum from a subject with allergic dermatitis was used as a source of INHIB, the HPLC increased the potency of INHIB by a factor of 50 to 2000 in multiple experiments. INHIB was also derived by HPLC fractionation of control serum from each of many other subjects, demonstrating that INHIB is a component of normal biological fluid and tissue that can be activated by purification and, presumably, by certain physiological events in vivo.

The present invention relates to INHIB as well as to its functional derivatives. The invention additionally pertains to processes for preparing and purifying INHIB, screening assays for INHIB, diagnostic and therapeutic uses of INHIB, and compositions containing INHIB or its functional derivatives.

In particular, the invention includes INHIB or its functional derivatives, which are substantially free of natural contaminants.

The purification of INHIB was achieved by a sequence of protein fractionation methodologies. Following each separation step, the fractions were screened for the ability to inhibit eosinophil killing of targets in vitro. The fractions containing the major inhibitory activity were forwarded to the next separation methodology.

The invention includes a method for recovering INHIB in substantially pure form which includes, but is not limited to, the following steps:

- (a) isolating INHIB from a sample;
- (b) ammonium sulfate precipitation of the INHIB-containing fraction;
- (c) controlled-pore glass bead chromatography of the INHIB-containing fraction;

-5-

(d) hydrophobic interaction chromatography of the INHIB-containing fraction;

(e) anion exchange chromatography of the INHIB-containing fraction;

(f) reverse-phase HPLC chromatography of INHIB; and

(g) recovering the filtrate obtained in step (f) in substantially pure form.

Purified and partially purified INHIB suppressed the killing of targets by eosinophils stimulated with granulocyte-macrophage colony-stimulating factor as well as with TNF. This demonstrates that the activity of INHIB is not cytokine-specific.

Purified and partially-purified INHIB suppressed the adherence of TNF-stimulated neutrophils to plastic surfaces. This demonstrates that the inhibitory activity of INHIB is not restricted to eosinophils but rather regulates a variety of inflammatory cell types.

The purification of INHIB also permits the generation of INHIB-related oligonucleotide and antibody probes that can be used to screen gene libraries for the molecular cloning of the INHIB gene. For logistical reasons, culture medium containing biosynthetic (recombinant) INHIB would be a superior source material compared to natural biological tissues or fluids for the purification of INHIB. The purification strategy presented here may be used to purify recombinant INHIB.

The invention includes the INHIB obtained by the above methods.

The invention further pertains to INHIB and its derivatives which are detectably labeled.

The invention is further directed to a method of diagnosing the presence and location of inflammation in a mammalian subject suspected of having an inflammation which comprises: (a) administering to said subject a composition

containing a detectably labeled binding molecule (e.g., antibody) capable of binding and identifying INHIB; and (b) detecting said binding molecule.

The invention also pertains to a method of diagnosing the presence and location of an inflammation in a mammalian subject suspected of having an inflammation which comprises: (a) incubating a biological sample from said subject suspected of containing INHIB in the presence of a detectably labeled binding molecule (e.g., antibody) capable of identifying INHIB; and (b) detecting said binding molecule which is bound in said sample. Said biological samples may include various tissues or body fluids such as blood serum, for example.

The invention is also directed to a method of treating inflammation in a mammalian subject which comprises providing to said subject in need of such treatment an amount of an anti-inflammatory agent sufficient to suppress said inflammation; wherein said anti-inflammatory is selected from the group consisting of: INHIB, a fragment of INHIB, a chemical derivative of INHIB, a variant of INHIB, and an analogue of INHIB.

The invention also includes the above method for treating inflammation wherein said anti-inflammatory agent is administered in a suitable carrier.

The invention also relates to a pharmaceutical composition for treating inflammation in a mammalian subject comprising administering an inflammation-reducing amount of an anti-inflammatory agent, wherein said agent is selected from the group consisting of: INHIB, a fragment of INHIB, a chemical derivative of INHIB, a variant of INHIB, and an analogue of INHIB.

The invention therefore includes novel methods for recovering and purifying the new INHIB molecule and its functional derivatives, uses for the molecule, including

-7-

diagnosing and treating inflammation in a mammalian subject, and novel compositions containing INHIB or its functional derivatives.

An understanding of this process of the inhibition of immunologic activity of cytokine-stimulated leukocytes such as eosinophils and neutrophils, and of the natural anti-inflammatory INHIB molecule itself, will aid in the development of its therapeutic and/or diagnostic uses in such fields as organ transplantation, allergy and oncology. This invention will enable those in the medical field to more effectively diagnose and treat inflammatory disease processes, and to utilize a quantitative assay for INHIB in order to monitor the time-course and/or intensity of ongoing clinical episodes of inflammation. The invention will further enable researchers to investigate the mechanisms of leukocyte interactions and leukocyte function, particularly eosinophils and neutrophils, in inflammation.

#### BRIEF DESCRIPTION OF THE FIGURES

Figure 1. The failure of eosinophils from a human subject (NR) to respond with enhanced cytotoxic function to TNF. Normal and NR eosinophils were purified and cultured in the presence of schistosomula targets, antibody, and either 100 U/ml or the indicated concentration of TNF. The killing of schistosomula targets was scored in duplicate or triplicate by microscopy at 36 to 40 hours.

A. Summary of 40 experiments, using eosinophil purified from 21 different donors (excluding NR).

B. Summary of 12 experiments using eosinophils purified from NR, each done in parallel with at least from experiment in group A. Experiments U and W were done while NR was undergoing severe contact dermatitis reactions. Experi-

-8-

ment Y was done while NR had extensive bruising as a result of an accidental fall.

C. The responsiveness of NR eosinophils (solid circle) and normal eosinophils (open triangles) to TNF at the indicated doses. The levels of killing in the absence of TNF are shown for NR (dotted line) and normal (dashed line) eosinophils.

Figure 2. Weak response of NR eosinophil to GM-CSF. In parallel with 3 experiments from Figs. 1A and 1B, the effect of GM-CSF was tested on the cytotoxic function of NR eosinophils that were unresponsive TNF (open symbols). The responsiveness was compared to that of normal eosinophils (solid symbols of the same shape).

Figure 3. The failure of NR neutrophils to respond with enhanced respiratory burst to TNF. Neutrophils from a normal subject (A) and NR (B) were isolated and incubated in physiological buffer at 37° for 10 minutes with (solid circles) or without (open circles) 100 U/ml of TNF. At time 0 the neutrophils were treated with 50 ug/ml of IgG aggregates and incubated further at 37°C. The release of H<sub>2</sub>O<sub>2</sub> over time was monitored by the scopoletin method. TNF alone did not stimulate the release of H<sub>2</sub>O<sub>2</sub> (not shown).

Figure 4. Specific binding of <sup>125</sup>I-TNF to NR neutrophils (solid circles) and to normal neutrophils from 2 different subjects (open symbols). 3 x 10<sup>6</sup> neutrophils were incubated overnight with either the indicated dose of labeled TNF (for total cpm bound) or that dose plus a 1000-fold excess of unlabeled TNF (for non-specific cpm bound). Non-specific cpm bound was subtracted from total cpm bound to determine the specific cpm bound at each concentration. At doses of less than 15 ng TNF/600ul, non-specific cpm bound were <26% of total cpm.

Figure 5. The ability of NR serum to cross-inhibit heterologous eosinophils from responding to TNF. The cytotoxic function of eosinophils was assayed in the presence (squares) or absence (circles) of 100 U/ml of TNF. Control heterologous serum (solid) or NR serum (open) was added to the cultures at the indicated concentrations. The horizontal lines indicate the level of killing with no serum added in the presence (dashes) or absence (dots) of TNF.

Figure 6. Variation over time in the ability of NR serum to inhibit the cytotoxic function of TNF-stimulated eosinophils. The cytotoxic function in the presence (100%) or absence (0%) of 100 U/ml of TNF was assayed. Heterologous (with respect to the eosinophils) sera were added to the cultures at a concentration of 10%. Samples 1-4 were taken from control donors.

Figure 7. Population distribution of the inhibitory activity in human sera. 100 anonymous serum samples were obtained from the Red Cross and tested as in Fig. 6 for the ability to inhibit the cytotoxic function of TNF-activated eosinophils at a concentration of 10%.

Figure 8. HPLC sizing analysis of INHIB.

A. 100  $\mu$ l of NR serum was injected on a TSK 400 column, and 1 ml fractions were collected. The fractions were heat-inactivated ( $56^\circ$  for 30 minutes) and added to TNF-stimulated eosinophils at a concentration of 20%. The cytotoxic function of the eosinophils was determined at 36 to 40 hours.

B. Emergence of INHIB activity when normal serum is chromatographed. The conditions of chromatography and bioassay were as for A.

Figure 9. Increase in the titer of INHIB as a consequence of HPLC sizing chromatography. NR serum (A, same sample as 8A), a human serum pool (lot 29309039, obtained from

-10-

Flow Laboratories) (B), a control serum sample with no inhibitory activity (C, same sample as 8B), and HPLC fractions 7 through 9 of these sera were tested for inhibitory activity in the eosinophil cytotoxicity assay at the indicated concentrations.

Figure 10. Sensitivity of INHIB to heat or trypsin treatment. The results in 3 experiments with INHIB from NR serum and 4 experiments with different control sera were essentially similar; in order to compare the results on the same scale, the level of killing in the presence of TNF with no inhibitors present was set equal to 100%. Values represent the mean % maximum killing  $\pm$  S.E. in 7 experiments. Killing was assayed under standard conditions when eosinophils were stimulated with: A, control medium; B, TNF plus 1% trypsin (2 x 0.5% trypsin w/z at 37°C for 30 minutes) plus soybean trypsin inhibitor (4-fold excess neutralizing units); C, TNF plus untreated INHIB; D, TNF plus treated INHIB (treatment = 80°C for 1 hour); E, TNF plus INHIB (1 hour trypsin, then SBTI); F, TNF plus INHIB (1 hour SBTI and trypsin); G, sample E with fresh INHIB added at end.

Figure 11. The inability of INHIB to protect L929 cells from TNF; time dependence of protection by the neutralizing monoclonal antibody 245-10E11. 100 U/ml of TNF was added to actinomycin D-treated (solid symbols) or untreated (open symbols) L929 cells. At the indicated times, 20% INHIB (circles, HPLC fractions 7 through 9) or 1000 neutralizing units of monoclonal antibody (triangles) was added to the cultures. The survival of cells was measured by the MTT method, and the relative protection by either of the inhibitors was calculated by comparison with the no inhibitor (0%) and no TNF (100%) control values.

Figure 12. The existence of a serum factor (INHIB) that inhibits the cytotoxic function of TNF-stimulated human

-11-

eosinophils. Normal human serum (solid symbols) and serum from a subject with frequent episodes of allergic dermatitis (open symbols) were added to the eosinophil cytotoxicity assay (components =  $10^5$  purified human eosinophils, antibody from Brazilian schistosomiasis patients, control medium [circles] or medium plus 100 U/ml of TNF [squares], and 100 mechanically transformed schistosomula) at the indicated concentrations. After a 40-hour incubation at 37°C, the killing of schistosomula targets was scored by microscopy. Values represent the mean of duplicate determinations.

Figure 13. Molecular weight estimate of the INHIB in normal (solid circle) and allergic dermatitis (open circle) sera. 100  $\mu$ l samples of serum were chromatographed on a TSK-400 HPLC column with a solvent of Hank's Balanced Salt Solution (buffered with 25 mM Hepes, pH 7.0, and containing penicillin and streptomycin). The eluted samples were tested in the eosinophil cytotoxicity assay, as described in Figure 12.

Figure 14. Increased potency of INHIB as a result of partial purification. Pooled fractions 17-19 from Figure 13 (squares) were compared for inhibitory activity to the sera (circles) from which they were derived. Samples from a normal (solid symbols) and allergic dermatitis subjects (open symbols) were tested at the indicated concentration in the eosinophil cytotoxicity assay, as described for Figure 12.

Figure 15. Enrichment of INHIB by ammonium sulfate precipitation. Fractions of serum were generated as described in the text, dialyzed in medium, and tested in the eosinophil cytotoxicity assay, as described for Figure 12.

Figure 16. Enrichment of INHIB by chromatography over controlled-pore glass beads. Samples were generated as described in the text and assayed as described for Figure 12.

-12-

The non-adherent runthrough (RT) usually contained some INHIB and could be recycled through the column.

Figure 17. Enrichment of INHIB by hydrophobic interaction chromatography. The active fraction from Figure 16 was chromatographed as described in the text. The elution of proteins was monitored by absorbance at 280 nm (top figure, fraction numbers indicated). After dialysis in medium, aliquots of these fractions were tested in the eosinophil cytotoxicity assay, as described for Figure 12 (bottom figure).

Figure 18. Enrichment of INHIB by anion exchange chromatography. The active fraction from Figure 17 was chromatographed as described in the text. The elution profiles and biological activities were determined as described for Figure 17.

Figure 19. Final purification of INHIB by reversed-phase HPLC. The active fraction from Figure 18 was chromatographed as described in the text. The elution profiles and biological activities were determined as for Figure 17, except that the results represent the mean of two experiments. The range of 0-100% is equal to the difference between the negative control and the maximum killing. The arrow shows the peak of purified INHIB.

Figure 20. SDS-polyacrylamide gel analysis of purified INHIB. The fraction numbers, corresponding to Figure 19 and the positions of molecular weight markers, are shown. The single species of purified INHIB is indicated by an arrow.

Figure 21. The ability of purified INHIB to inhibit neutrophil adherence to plastic. The samples from Figure 19 were tested in two experiments as described in the text. The range of 0-100% is equal to the difference between the negative control and maximum adherence, assayed in duplicate in each of two experiments.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

One aspect of the present invention relates to the discovery of a natural inhibitor of cytokine-stimulated leukocyte immunological activity, referred to as INHIB. The invention is directed toward substantially pure INHIB and its "functional derivatives."

The term "leukocyte" refers to white blood cells, including neutrophils, eosinophils, and monocytes.

By the terms "activated," "activation," or "immunologic activity" is meant the stimulation of subject cells to behave in a certain biologically expected manner, i.e., for neutrophils to become adherent or eosinophils to become cytotoxic, for example.

The term "cytokine" refers to a compound capable of activating leukocytes, in particular, eosinophils and neutrophils. Cytokines are, in general, proteins or glycoproteins having a molecular weight of 10-100 kDa. Examples of cytokines are disclosed by Stephenson (In: Animal Cell Biotechnology, Vol. 2, Spier, R.E., et al., eds., Academic Press, pp. 41-45 (1985)). Although any compound capable of regulating INHIB inhibition of the immunological activities of leukocytes, such as cytotoxicity or adherence, may be employed in accordance with the present invention, it is preferable to employ a cytokine, and it is especially preferable to employ the cytokine TNF or granulocyte-macrophage colony-stimulating factor (GMCSF), or eosinophil cytotoxic enhancing factor (ECEF) and their recombinant forms. See, for example, Wang et al., Science 228:149 (1985) for the cloning and purification of recombinant TNF; and Wong et al., Science 228:810 (1985) for the cloning and purification of recombinant GMCSF. The regulation of human eosinophil function by cytokines is

described in Silberstein *et al.*, Immunol. Today 8:380-385 (1987).

The term "functional derivatives" is intended to include the "fragments," "variants," "analogues," or "chemical derivatives" of a molecule. A "fragment" of a molecule such as INHIB is meant to refer to any polypeptide subset of that molecule. A "variant" of a molecule such as INHIB is meant to refer to a naturally occurring molecule substantially similar to either the entire molecule, or a fragment thereof. An "analogue" of a molecule such as INHIB is meant to refer to a non-natural molecule substantially similar to either the entire molecule or a fragment thereof. A molecule is said to be "substantially similar" to another molecule if the sequence of amino acids in both molecules is substantially the same, and if both molecules possess a similar biological activity. Thus, provided that two molecules possess a similar activity, they are considered variants as that term is used herein even if one of the molecules contains additional amino acid residues not found in the other, or if the sequence of amino acid residues is not identical.

As used herein, a molecule is said to be a "chemical derivative" of another molecule when it contains additional chemical moieties not normally a part of the molecule. Such moieties may improve the molecule's solubility, absorption, biological half-life, etc. The moieties may alternatively decrease the toxicity of the molecule, eliminate or attenuate any undesirable side effect of the molecule, etc. Examples of moieties capable of mediating such effects are disclosed in Remington's Pharmaceutical Sciences (1980) and will be apparent to those of ordinary skill in the art.

One screening method for determining whether a given compound is an INHIB functional derivative comprises, for example, immunoassays employing RIA or ELISA methodologies,

based on the production of specific neutralizing antibodies (monoclonal or polyclonal) to natural INHIB. Other suitable screening methods will be readily apparent to those of skill in the art.

The INHIB molecule disclosed herein is said to be "substantially free of natural contaminants" if preparations which contain it are substantially free of materials with which this product is normally and naturally found.

For purposes of the present invention, preferred methods of purification include, without being limiting, the following steps:

- a) Fractionating the biological sample containing INHIB based on precipitating proteins at high ionic strength. Proteins differ in their solubility in concentrated salt solutions and hence can be separated from one another by precipitation at high ionic strength. The preferred salt is ammonium sulfate, although other salts are known and may be used.
- b) Protein separation based on hydrogen bonding to separate the contaminating proteins from the sample containing INHIB using hydrophobic interaction chromatography. This step is preferably chromatography over controlled-pore glass beads such as those available from Sigma Chemical Co., St. Louis, Mo., when the biological sample is serum. Alternatively, for other samples, DEAE-cellulose-exchange chromatography may be used. In addition, affinity chromatography such as affi-blue gel affinity chromatography could be used at this step.
- c) Protein separation based on hydrogen bonding, for example, using hydrophobic interaction chromatography.

- d) Protein separation based on carboxyl and amino charges, for example, anion exchange chromatography.
- e) Separating substances based upon their weakly polar or non-polar moieties using ion-exchange chromatography using reverse-phase HPLC.

In particular, the following methods and materials were found to be particularly useful: (1) ammonium sulfate precipitation, (2) chromatography over controlled-pore glass beads, (3) hydrophobic interaction chromatography using a silica-phenyl matrix, (4) anion exchange chromatography using a silica-DEAE matrix, and (5) reverse-phase HPLC using a silica-alkyl (C4) matrix.

Also contemplated by the present invention are purified INHIB fragments or its derivatives manufactured using organic synthesis or recombinant DNA techniques, or by proteolysis.

It will be appreciated by those of skill in the art that other purification steps may be substituted for the preferred method described above. For example, instead of using chromatography over controlled-pore glass beads in step (b), one could equally use affi-blue gel chromatography to remove serum albumin from a serum sample containing INHIB. (See Travis et al., Biochem. J. 157:301-306 (1976); Yip et al., PNAS 78:1601).

By the term "mammal" is intended all mammals in which INHIB may be obtained from tissue or fluid and for which the inhibition of eosinophilic or neutrophilic immunologic activity, for example, and other uses of the present invention, described below, have a beneficial effect. Foremost among such mammals are humans; however, the invention is not intended to be so limiting, it being within the contemplation of the invention to treat any and all mammals which may experience the beneficial effects of the invention.

The present invention also includes methods of detecting INHIB or its functional derivatives in a sample or subject. For example, antibodies specific for INHIB, or its functional derivatives, may be detectably labeled with any appropriate ligand, for example, a radioisotope, an enzyme, a fluorescent label, a paramagnetic label, or a free radical. The presence of inflammation may be detected through the use of such detectably labeled materials. Methods of making and detecting such detectably labeled antibodies or their functional derivatives are well known to those of ordinary skill in the art.

The term "antibody" refers to monoclonal or monospecific antibodies which have a substantially homogeneous population of molecules. Monoclonal antibodies directed toward INHIB may be obtained by methods known to those skilled in the art. See, for example, Kohler and Milstein, Nature 256:495-497 (1975) and U.S. Patent No. 4,376,110. These publications, as well as those mentioned hereunder, are incorporated herein by reference. Unless defined otherwise, various terms used herein have the same meaning as is well understood in the art to which the invention belongs.

The term "antibody" is also meant as well to include both intact molecules as well as fragments thereof, such as, for example, Fab and  $F(ab')_2$ , which are capable of binding to antigen.

It is possible to use antibodies, or their functional derivatives, to detect or diagnose the presence and location of an inflammation in a mammalian subject suspected of having an inflammation by utilizing an assay for INHIB, comprising incubating a biological sample from said subject suspected of containing INHIB in the presence of a detectably labeled binding molecule (e.g., antibody) capable of identifying

INHIB, and detecting said binding molecule which is bound in a sample.

Thus, in this aspect of the invention, a biological sample may be treated with nitrocellulose, or other solid support which is capable of immobilizing cells, cell particles or soluble protein. The support may then be washed with suitable buffers followed by treatment with the detectably labeled INHIB-specific antibody. The solid phase support may then be washed with the buffer a second time to remove unbound antibody. The amount of bound label on the antibody may then be detected by conventional means.

One embodiment for carrying out the assay of the present invention on a sample containing INHIB, comprises:

- (a) contacting a sample suspected containing INHIB with a solid support to effect immobilization of INHIB;
- (b) contacting said solid support with a detectably labeled INHIB-specific antibody;
- (c) incubating said detectably labeled INHIB-specific antibody with said support for a time sufficient to allow the INHIB-specific antibody to bind to the immobilized INHIB;
- (d) separating the solid phase support from the incubation mixture obtained in step (c); and
- (e) detecting the bound label and thereby detecting and quantifying INHIB.

This aspect of the invention relates to a method for detecting INHIB or fragment thereof in a sample comprising

- (a) contacting a sample suspected of containing INHIB with an INHIB-specific antibody or fragment thereof which binds to INHIB; and
- (b) detecting whether a complex is formed.

Of course, the specific concentrations of detectably labeled antibody and INHIB, the temperature and time of

incubation, as well as other assay conditions may be varied, depending on various factors including the concentration of INHIB in the sample, the nature of the sample, and the like. The binding activity of a given lot of antibody directed toward INHIB may be determined according to well known methods. Those skilled in the art will be able to determine operative and optimal assay conditions for each determination by employing routine experimentation.

Other such steps as washing, stirring, shaking, filtering and the like may be added to the assays as is customary or necessary for the particular situation.

One of the ways in which the INHIB-specific antibody can be detectably labeled is by linking the same to an enzyme. This enzyme, in turn, when later exposed to an appropriate substrate, will react with the substrate in such a manner as to produce a chemical moiety which can be detected, for example, by spectrophotometric, fluorometric or by visual means. Enzymes which can be used to detectably label the INHIB-specific antibody include, but are not limited to, malate dehydrogenase, staphylococcal nuclease, delta-V-steroid isomerase, yeast alcohol dehydrogenase, alpha-glycerophosphate dehydrogenase, triose phosphate isomerase, horseradish peroxidase, alkaline phosphatase, asparaginase, glucose oxidase, beta-galactosidase, ribonuclease, urease, catalase, glucose-VI-phosphate dehydrogenase, glucoamylase and acetylcholine esterase.

The INHIB-specific antibody may also be labeled with a radioactive isotope which can be determined by such means as the use of a gamma counter or a scintillation counter or by audioradiography. Isotopes which are particularly useful for the purpose of the present invention are:  $^3\text{H}$ ,  $^{125}\text{I}$ ,  $^{131}\text{I}$ ,  $^{35}\text{S}$ ,  $^{14}\text{C}$ , and  $^{51}\text{Cr}$ .

-20-

It is also possible to label the INHIB-specific antibody with a fluorescent compound. When the fluorescently labeled antibody is exposed to light of the proper wave length, its presence can then be detected due to the fluorescence of the dye. Among the most commonly used fluorescent labelling compounds are fluorescein isothiocyanate, rhodamine, phycoerytherin, phycocyanin, allophycocyanin,  $\alpha$ -phthaldehyde and fluorescamine.

The INHIB-specific antibody can also be detectably labeled using fluorescence emitting metals such as  $^{152}\text{Eu}$ , or others of the lanthanide series. These metals can be attached to the INHIB-specific antibody using such metal chelating groups as diethylenetriaminepentaacetic acid (DTPA) or ethylenediaminetetraacetic acid (EDTA).

The INHIB-specific antibody also can be detectably labeled by coupling it to a chemiluminescent compound. The presence of the chemiluminescent-tagged INHIB-specific antibody is then determined by detecting the presence of luminescence that arises during the course of a chemical reaction. Examples of particularly useful chemiluminescent labeling compounds are luminol, isoluminol, theromatic acridinium ester, imidazole, acridinium salt and oxalate ester.

Likewise, a bioluminescent compound may be used to label the INHIB-specific antibody of the present invention. Bioluminescence is a type of chemiluminescence found in biological systems in which a catalytic protein increases the efficiency of the chemiluminescent reaction. The presence of a bioluminescent protein is determined by detecting the presence of luminescence. Important bioluminescent compounds for purposes of labeling are luciferin, luciferase and aequorin.

-21-

Detection of the INHIB-specific antibody may be accomplished by a scintillation counter, for example, if the detectable label is a radioactive gamma emitter, or by a fluorometer, for example, if the label is a fluorescent material. In the case of an enzyme label, the detection can be accomplished by colorimetric methods which employ a substrate for the enzyme. Detection may also be accomplished by visual comparison of the extent of enzymatic reaction of a substrate in comparison with similarly prepared standards.

The detection of foci of such detectably labeled antibodies is indicative of a site of inflammation. In one embodiment, as described above, this examination for inflammation is accomplished by removing samples of tissue or blood and incubating such samples in the presence of detectably labeled antibodies. In a preferred embodiment, this technique is accomplished in a non-invasive manner through the use of magnetic imaging, fluorography, etc. For example, such a diagnostic test may be employed in monitoring organ transplant recipients for early signs of potential tissue rejection. Such assays may also be conducted in efforts to determine a subject's clinical status in rheumatoid arthritis and other chronic inflammatory diseases.

INHIB is involved in inflammatory processes. The term "inflammation" is meant to include reactions of both the specific and non-specific defense systems. A specific defense system reaction is a specific immune system reaction response to an antigen. Examples of a specific defense system reaction include the antibody response to antigens such as rubella virus, and delayed-type hypersensitivity response mediated by T-cells (as seen, for example, in individuals who test "positive" in the Mantoux test).

A non-specific defense system reaction is an inflammatory response mediated by leukocytes incapable of immunological

-22-

memory. Such cells include granulocytes, macrophages, neutrophils, eosinophils, etc. Examples of a non-specific defense system reaction include the immediate swelling at the site of a bee sting, the reddening and cellular infiltrate induced at the site of a burn, and the collection of polymorphonuclear (PMN) leukocytes at sites of bacterial infection (e.g., pulmonary infiltrates in bacterial pneumonias, pus formation in abscesses).

It will be appreciated that the present invention will be easily adapted to the diagnosis, monitoring, and treatment of inflammatory disease processes such as rheumatoid arthritis, acute and chronic inflammation, post-ischemic (reperfusion) leukocyte-mediated tissue damage, acute leukocyte-mediated lung injury (e.g., Adult Respiratory Distress Syndrome), and other tissue- or organ-specific forms of acute inflammation (e.g., glomerulonephritis).

The term "treatment" is meant to include the prevention, elimination and attenuation or amelioration of the conditions of pathology described below.

As would be apparent to one of ordinary skill in the art, the therapeutic effects of INHIB may be obtained by providing to a patient the entire INHIB molecule, or any therapeutically active peptide fragment thereof.

As is also apparent, the therapeutic advantages of INHIB may be augmented through the use of INHIB mutants or variants possessing additional amino acid residues added to enhance its coupling to a carrier or to enhance the activity of INHIB. The scope of the present invention is further intended to include mutant forms of INHIB (including INHIB molecules which lack certain amino acid residues, or which contain altered amino acid residues, so long as such mutant INHIB molecules exhibit the capacity to affect cellular function).

-23-

The INHIB molecule of the present invention and its functional derivatives can be formulated according to known methods of preparing pharmaceutically useful compositions, whereby these materials or their functional derivatives are combined in a mixture with a pharmaceutically acceptable carrier vehicle. The objects and advantages of the present invention may be achieved by such a composition comprising INHIB when administered in said suitable pharmaceutically acceptable (sterile and non-toxic) carrier to mammals suffering from inflammatory disease conditions, cancer, or the like. Suitable vehicles and their formulation are described, for example, in Remington's Pharmaceutical Sciences (16th ed., Osol, A., Ed., Mack, Easton, PA (1980)). In order to form a pharmaceutically acceptable composition suitable for effective administration, such compositions will contain a therapeutically effective amount of INHIB molecule, or its functional derivatives (an inflammation-reducing amount), together with a suitable amount of carrier vehicle.

As used herein, the preparations and compositions of the present invention mediate suppression of, attenuate, or ameliorate inflammation, if, when provided to an animal, their administration results in either a decrease in the inflammation or prevalence of inflammation-associated cells. It is to be understood that the compositions and preparations of the present invention are to be provided to an animal in amounts and at frequencies capable of successfully mediating the suppression of said inflammation. The proper amounts and frequencies will be readily discernable to those of skill in the art.

Compositions within the scope of this invention include all compositions wherein each of the components thereof is contained in an amount effective to achieve its intended purpose.

-24-

Suitable pharmaceutically acceptable carriers may comprise excipients and auxiliaries which facilitate processing of the active compounds into preparations which can be used pharmaceutically. These will be readily apparent to those of skill in the art.

A preferred product of the invention is a sterile pharmaceutical composition for therapeutic use containing INHIB or its functional derivatives, which is suitable for intravenous administration. The product may be in lyophilized form to be reconstituted for use by addition of a suitable carrier, or diluent, or it may be in the form of an aqueous solution.

For reconstitution of a lyophilized product in accordance with this invention, one may employ a sterile diluent, which may contain materials generally recognized for approximating physiological conditions and/or as required by governmental regulation. In this respect, the sterile diluent may contain a buffering agent to obtain a physiologically acceptable pH, such as sodium chloride, saline, phosphate-buffered saline, and/or other substances which are physiologically acceptable and/or safe for use. In general, the material for intravenous injection in humans should conform to regulations established by the Food and Drug Administration, which are available to those in the field.

The pharmaceutical composition may also be in the form of an aqueous solution containing many of the same substances as described above for the reconstitution of a lyophilized product.

As mentioned above, the products of the invention may be incorporated into pharmaceutical preparations which may be used for therapeutic purposes. However, the term "pharmaceutical preparation" is intended in a broader sense herein to include preparations containing a protein composition in

accordance with this invention, used not only for therapeutic purposes but also for reagent or diagnostic purposes as known in the art, or for tissue culture. The pharmaceutical preparation intended for therapeutic use should contain a "pharmaceutically acceptable" or "therapeutically effective amount" of INHIB, i.e., that amount necessary for preventative or curative health measures. If the pharmaceutical preparation is to be employed as a reagent or diagnostic, then it should contain reagent or diagnostic amounts of INHIB.

A composition is said to be "pharmaceutically acceptable" if its administration can be tolerated by a recipient patient. Such an agent is said to be administered in a "therapeutically effective amount" if the amount administered is physiologically significant. An agent is "physiologically significant" if its presence results in a detectable change in the physiology of a recipient patient.

By definition, one unit of INHIB activity will produce 50% inhibition of cytokine-activated eosinophil cytotoxicity or neutrophil adherence at an eosinophil concentration of  $2 \times 10^6$  cells/ml and a neutrophil concentration of  $2 \times 10^6$  cells/ml in a standardized in vitro assay system. INHIB at a concentration of 20 U/ml produces a maximal inhibition of 100% at the same cell concentration.

The therapeutic and/or diagnostic dosage administered will be dependent upon the particular inflammatory condition involved and may be dependent upon the age, weight, height, sex, general medical condition, and kind of concurrent treatment, if any, of the mammalian subject.

Methods useful for administering the molecules of the present invention include topical, subcutaneous, intra-articular, intraperitoneal, intrapleural, or intraocular. When administering INHIB or its functional derivatives by

injection, the administration may be by continuous infusion, or by single or multiple boluses.

The effective molecule useful in the methods of the present invention may be employed in such forms as, for example, sterile suspensions for injection or encapsulated for targeting to specific tissue sites with antibodies directed to inflammation-related cell surface structures.

Additional pharmaceutical methods may be employed to control the duration of action. Controlled release preparations may be achieved through the use of polymers to complex or absorb INHIB or its functional derivatives. The controlled delivery may be achieved by selecting appropriate macromolecules (for example, polyesters, polyamino acids, polyvinyl, pyrrolidone, ethylenevinylacetate, methylcellulose, carboxymethylcellulose, or protamine, sulfate) and the appropriate concentration of macromolecules as well as the methods of incorporation, in order to control release.

Another possible method useful in controlling the duration of action by controlled release preparations is incorporation of the INHIB molecule or its functional derivatives into particles of a polymeric material such as polyesters, polyamino acids, hydrogels, poly(lactic acid), or ethylene vinylacetate copolymers.

Alternatively, instead of incorporating INHIB or its functional derivatives into polymeric particles, it is possible to entrap these materials in microcapsules prepared, for example, by coacervation techniques or by interfacial polymerization (for example, hydroxymethylcellulose or gelatine-microcapsules and poly-(methylmethacrylate) microcapsules, respectively), in colloidal drug delivery systems (for example, liposomes, albumin microspheres, microemulsions, nanoparticles, and nanocapsules), or in macroemulsions. Such

-27-

techniques are disclosed in Remington's Pharmaceutical Sciences (1980).

#### EXAMPLES

Having now fully described the present invention, the same will be more clearly understood by reference to certain specific examples which are included herewith for purposes of illustration only and are not intended to be limiting of the invention, unless specified.

Cytokines. Recombinant human tumor necrosis factor (TNF), produced by in E. coli and purified (Wang et al., Science 228:149 (1985)), was provided by Cetus Corporation. Unless otherwise specified, TNF was used at a concentration of 100 U/ml, the optimal dose for the eosinophil cytotoxicity assay (Silberstein et al., Proc. Natl. Acad. Sci. USA 83:1055 (1986)). For some experiments, purified monoclonal antibody 245-10E11 (Fendly et al. Hybridoma 6:359 (1987)) was used to neutralize the activity of TNF. The neutralizing titer of the antibody was determined by the L929 cell cytotoxicity assay (Wang et al., Science 228:149 (1985)). Recombinant human granulocyte-macrophage colony-stimulating factor (GM-CSF), produced by COS cells and purified, was provided by Dr. Judith C. Gasson. GM-CSF was used at a final concentration of 20 pM, the optimal dose in the eosinophil cytotoxicity assay (Silberstein et al., J. Immunol. 137:3290 (1986)).

Purified TNF was radioiodinated using IODO-BEADS (Pierce Chemical Co.). Autoradiography of  $^{125}\text{I}$ -TNF following SDS-PAGE showed that the iodinated protein and the unlabeled TNF migrated in the same fashion. The majority (50-100%) of the initial bioactivity was recovered, as determined by the L929 cytotoxicity assay (Wang et al., Science 228:149 (1985)). The

-28-

specific activity of the labeled TNF was  $0.7-7 \times 10^8$  cpm/ug (0.71-7.1 mCi/uM).

Blood donors. Venous blood was obtained from laboratory personnel for the preparation of serum, eosinophils and neutrophils. Some of the donors for eosinophil studies had moderately elevated eosinophil counts in association with allergies and/or asthma (total eosinophil counts ranged from 1 to 18% of total leukocytes for these studies). A human subject (NR) was identified whose eosinophils and neutrophils were uniquely (in a study population of 38) unresponsive to TNF in immunological assays *in vitro*. Serum from this subject and 5 of 122 other subjects tested, inhibited eosinophil cytotoxic function in a dose-dependent manner.

One hundred anonymous serum samples were also supplied by the American Red Cross Blood Services, Northeast Region (Dedham, MA; for use in a studies related to Figure 7 and Table 1.

Antibody. Antibody to schistosomula of the human blood fluke *S. mansoni* was obtained from Brazilian schistosomiasis patients, as described previously (Silberstein *et al.*, *Proc. Natl. Acad. Sci. USA* 83:1055 (1986)).

#### EXAMPLE ONE

##### Preparation of Serum, Eosinophils, and Neutrophils

Blood for the preparation of serum was collected in glass tubes, incubated at 37°C for 1 hour and then overnight at 4°C. The serum was clarified by centrifugation and stored frozen at -20°C.

Heparinized blood for the preparation of eosinophils was processed by a sequence of dextran sedimentation and discon-

tinuous metrizamide density gradient centrifugation (Vadas *et al.*, J. Immunol. 122:1228 (1979)). The purity of eosinophil preparations, as evaluated by examination of Wright's-Giemsa stained slides, ranged from 80 to 99%.

Heparinized blood for the preparation of neutrophils was processed by a sequence of dextran sedimentation and Ficoll-Hypaque centrifugation (Boyum *et al.* Scand. J. Clin. Lab. Invest. 21 (Suppl. 97):77 (1968)). Erythrocytes were removed by hypotonic lysis. The neutrophil preparations were essentially free of mononuclear cells and contained <10% eosinophils.

#### EXAMPLE TWO

##### Assay of Eosinophil Cytotoxic Function

Eosinophils were washed two times and suspended at a concentration of  $2 \times 10^6$ /ml in assay medium (minimal essential medium with Earle's salts, supplemented with 25 mM HEPES, 2 mM glutamine, 100 U/ml penicillin G, 100 ug/ml streptomycin, and 10% heat-inactivated fetal calf serum, all from GIBCO, Grand Island, NY).

Mechanically-transformed schistosomula of Schistosoma mansoni were prepared as described previously (Ramalho-Pinto *et al.* Exp. Parasitol. 36:360 (1974)), washed four times, and suspended at a concentration of 2000/ml in assay medium. Cytokines, heat-inactivated anti-schistosomula serum, and test inhibitor were diluted to five times the final concentration in assay medium. Unless otherwise specified, 50 ul each of cytokine (or control medium), inhibitor (or control medium), and eosinophils, were added to wells of a tissue culture plate (96-well, round-bottomed). Some experiments that did not involve the study of inhibitors, were done using final volumes

-30-

of 200  $\mu$ l, with four-times concentrated stocks of cytokine and antibody.

The plates were incubated for 30 minutes at 37°C in a sealed, humidified box. After this period, 50  $\mu$ l each of antibody and schistosomula were added, and the plates were incubated at 37°C in a sealed, humidified box. For experiments in which the inhibitor was removed, the contents of microwells were transferred to 12 x 75 mm polypropylene tubes, diluted with 5 ml of medium, and centrifuged at 500 g for 5 minutes. The supernatant was aspirated, and the eosinophils and schistosomula in the pellet were recultured in 250  $\mu$ l of assay medium with fresh inhibitor and cytokine.

The killing of schistosomula was scored by microscopy at approximately 40 hours, using uptake of toluidine blue and lack of motility as indications of death. The death of cultured schistosomula was negligible when either antibody or eosinophils was absent from the cultures.

TABLE ONE

Irreversibility of the Activation of INHIB

% Reduction in TNF-enhanced Cytotoxic Function(a)

% Inhibitor	Serum(b)	INHIB(c)	INHIB + Serum(d)
20	0	100	97
10	4	54	73
5	0	35	0
2.5	0	0	0
1.2	0	3	0

(a) % decrease in TNF-enhanced killing of schistosomula; 37%

-31-

killed by TNF-stimulated eosinophils (0% decrease); 5% killed by unstimulated eosinophils (100% decrease).

- (b) serum from a control subject with no inhibitory activity.
- (c) pooled fractions containing activated INHIB, prepared by HPLC sizing chromatography (dilution factor = 50 with respect to serum, due to chromatography and pooling of fractions).
- (d) the indicated concentration of INHIB added to an equal volume of the serum from which it was derived.

### EXAMPLE THREE

#### Assay of Neutrophil Function

The ability of neutrophils to kill schistosomula was assayed as for eosinophils, except that an effector to target ratio of 5000: 1 was used.

To determine neutrophil adherence to plastic, neutrophils were suspended at a concentration of  $10^5$  cells/200  $\mu$ l of assay medium in the presence or absence of 100 U/ml TNF and allowed to settle in round-bottomed microtiter wells at 37°C for 2 hours. After this period, the adherence of neutrophils to the plastic surface was assayed by one of two methods. As described previously (Silberstein *et al.* Proc. Natl. Acad. Sci. USA 83:1055 (1986); Arnaout *et al.* J. Clin. Invest. 78:597 (1986)), the wells were examined using an inverted microscope. In the absence of TNF, there was very little adherence of neutrophils to the plastic, and most of the cells were in a pellet at the bottom of the wells. Usually, in the presence of TNF, neutrophils were seen covering the sides of the wells.

As an alternative method of measuring the adherence of neutrophils, non-adherent neutrophils were washed away with warm saline, and a solution containing 0.1% Triton X-100,

-32-

0.4 mM 2-2' azino-di-3-ethyl-benzthiazoline-6-sulfonate plus 0.003% hydrogen peroxide in pH 4.0, 0.05 M sodium citrate substrate was added to the wells. The generation of colored substrate (absorbance monitored at 405 nm) was dependent on the quantity of neutrophil myeloperoxidase in the wells.

Throughout the purification procedure there was strong correspondence between the ability of a test sample to suppress eosinophil cytotoxic function and its ability to suppress neutrophil adherence. Thus, purified INHIB is also able to suppress neutrophil functions and other leukocyte functions related to inflammation.

#### EXAMPLE FOUR

##### Measurement of Eosinophil and Neutrophil Production of H<sub>2</sub>O<sub>2</sub>

Production of H<sub>2</sub>O<sub>2</sub> was measured by a modification of the method of Root *et al.* (*J. Clin. Invest.* 55:945 (1975)). Purified cells were washed and resuspended in buffer (4 mM sodium phosphate, pH 7.4, 128 mM sodium chloride, 12 mM potassium chloride, 1 mM calcium chloride, 2 mM magnesium chloride, and 2 mM glucose) at a concentration of 10<sup>6</sup>/ml. The cells were then placed in a cuvette (10 x 10 x 48 mm acrylic, Sarstedt, Princeton, NJ) with 5  $\mu$ l of horseradish peroxidase stock (6.25 mg/ml buffer, Sigma), 10  $\mu$ l of scopoletin stock (1 mM in buffer, Sigma), 10  $\mu$ l of control buffer or TNF (for some experiments), and maintained at 37°C. Fluorescence was monitored at 460 nm (with excitation at 350 nm) by a Perkin-Elmer model MPF-44B fluorescent spectrophotometer (Perkin-Elmer, Norwalk, CT). When baseline fluorescence had been established for 5 minutes, the cells were stimulated either with 10  $\mu$ l of phorbol myristate acetate (1 mg/ml in ethanol) or with IgG aggregates. The decrease in fluorescence, which

-33-

is proportional to the production of  $H_2O_2$ , was recorded by a Perkin-Elmer model 056-1001 recorder.

IgG aggregates were prepared by known methods. Chromatographically purified human IgG (Organon Teknika-Cappel) was dissolved in  $H_2O_2$  assay buffer at a concentration of 10 mg/ml. This solution was heated in a water bath at 62°C for 25 minutes. Control preparations of IgG that were not heat-aggregated did not stimulate detectable production of  $H_2O_2$  by eosinophils or neutrophils.

#### EXAMPLE FIVE

##### Assay Of The Biological Activity of TNF

The biological activity (expressed in units) of TNF was assayed as described (Wang *et al.* *Science* 228:149 (1985)), using the TNF-sensitive L929 cell line. The cells were cultured either with 1 ug/ml actinomycin D for 16 hours (seeded initially at  $10^5$  cells/microwell) or without actinomycin D for 28 hours (seeded originally at  $2 \times 10^4$  cells/-microwell). The viability of L929 cells was determined by the spectrophotometric measurement of the reduction of the tetrazolium salt MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide) to formazan by the mitochondrial enzyme succinate dehydrogenase, a reaction which occurs only in living cells (Denizot *et al.* *J. Immunol. Meth.* 89:271 (1986)).

#### EXAMPLE SIX

##### Measurement of Neutrophil Surface Membrane Receptors for TNF

Neutrophils were incubated overnight at 4°C in Hank's balanced salt solution plus 1% sucrose in the presence of

-34-

various doses of  $^{125}\text{I}$ -labeled TNF in the presence or absence of a 1000-fold excess of unlabeled TNF, as described previously (Creasey *et al.*, PNAS USA **84**:3293 (1987)). After this period, the neutrophils were washed in cold buffer, and the bound radiolabel was counted. Non-specific binding (radiolabel bound in the presence of unlabeled TNF) was subtracted from total bound radiolabel (in the absence of unlabeled TNF) to calculate specific binding.

#### EXAMPLE SEVEN

##### HPLC Sizing Analysis

100  $\mu\text{l}$  samples of serum were chromatographed on the following HPLC sizing columns: TSK-250 and TSK-4000 BioSil 7 x 600 mm columns (BioRad, Richmond CA) and a Zorbax G-250 column (Dupont, Wilmington DE). The chromatography solvent consisted of 0.9% sodium chloride, 25 mM HEPES at pH 7.0, 100 U/ml penicillin G, and 100  $\mu\text{g}/\text{ml}$  of streptomycin. The molecular weight of the inhibitory component (INHIB) was estimated by size exclusion HPLC at 80 to 100 kilodaltons (kD). When control serum samples with no detectable INHIB were chromatographed in the same manner, INHIB of the same apparent molecular weight was detected. Partial purification of INHIB by molecular sizing HPLC increased the potency of INHIB.

In order to discover the population distribution of the inhibitory activity identified in NR serum, 22 sera from lab personnel and 100 anonymous sera from the Red Cross were tested in the eosinophil cytotoxicity assay. Eleven of these sera reduced TNF-enhanced killing of targets by >50% and 4 sera reduced TNF-enhanced killing by >90% (data not shown). The inhibitor was also detectable in a sample of pooled human

-35-

type AB serum, that was obtained from Flow laboratories (lot# 29309039).

#### EXAMPLE EIGHT

##### The purification of INHIB from Human Serum

Volumes up to 350 ml of human serum, either pooled or from a single donor, were processed for purification of INHIB by the following steps:

1. Ammonium sulfate precipitation: Serum was brought to 50% saturation with ammonium sulfate (29.1 g/100 ml) and mixed for 24 to 48 hours at 4°C. The slurry was centrifuged at approximately 10,000 x g for 15 minutes. The resulting pellet (50P) was saved. The supernatant (50S) was brought to 65% saturation (addition of 9.2 g ammonium sulfate/100 ml). This was mixed in the cold and centrifuged as before. The resulting supernatant (65S) was saved. The pellet (65P) contained INHIB (Figure 15), and was dialyzed in phosphate-buffered saline (PBS) for the next purification step.

2. Chromatography over controlled-pore glass beads: The 65P fraction was dissolved in PBS + 0.04% sodium azide, dialyzed in more PBS, and diluted in PBS to 10 times the original volume of serum. This solution was mixed with controlled-pore glass beads (CPG Inc., Fairfield, NJ) at a ratio of 1 g beads: 10 ml diluted 65P, overnight at 4°C. The beads were packed in a column with a height to width ratio of > 50:1, washed with PBS, and eluted with 30% and then 50% ethylene glycol. INHIB was recovered in the 50% eluate (Figure 16).

3. Hydrophobic interaction chromatography: The sample was dialyzed in buffer A (0.1 M sodium phosphate, pH 7.0, plus

-36-

0.6 M ammonium sulfate) and loaded on a Bio-Gel TSK-phenyl 5-PW HPLC column (75 x 7.5 mm, Bio-Rad, Richmond, CA) in the same buffer. The column was washed 15 minutes with buffer A and then eluted with a 45 minute gradient (flow = 1 ml/minute) to buffer B (0.01 M sodium phosphate, pH 7.0 plus 30% ethylene glycol). This was followed by a 15 minute wash with buffer B. INHIB was recovered in fraction 52 (1 minute fractions, beginning with injection) at approximately 25% solution B (Figure 17).

4. Anion exchange chromatography: The fraction was dialyzed in buffer C (0.02 M Tris, pH 8.0) and loaded on a DEAE-5PW HPLC column (7.5 x 75 mm, Kratos, Ramsey, NJ). The column was washed for 15 minutes with buffer C and eluted with a 30 minute gradient (flow = 1 ml/minute) from buffer C to buffer D (0.02 M Tris, pH 8.0 plus 0.5 M ammonium sulfate). This was followed by a 15 minute wash with buffer D. INHIB was recovered in fractions 25 to 27 (Figure 18).

5. Reversed-phase HPLC: The pooled fractions were loaded on a Vydac C4 column (4.6 x 250 mm, the Nest Group, Southboro, MA). The column was washed with solution E (0.1% trifluoroacetic acid) for 20 minutes and eluted with a 30 minute gradient from solution E to solution F (0.1% trifluoroacetic acid plus 50% acetonitrile). INHIB was recovered in fraction 40, corresponding to the indicated peak (Figure 19).

Analysis of this material by SDS-polyacrylamide gel showed a single polypeptide species with a molecular weight of approximately 70,000 (Figure 20).

Affi-Gel Blue (Bio-Rad) fractionation of ammonium sulfate-precipitated human serum was also utilized in place of step (2), chromatography over controlled-pore glass beads. This step also greatly enhanced INHIB activity in the serum albumin-reduced fraction (greater than 100%) as assessed by the eosinophil cytotoxicity assay and neutrophil adherence

-37-

assay. There was some remaining activity in the albumin fraction which was not removed. (See Travis *et al.*, Biochem. J. 157:301-306 (1976); Yip *et al.*, PNAS 78:1601).

#### Mechanism of Action of INHIB

INHIB did not have detectable toxic effects on eosinophils. The presence of INHIB did not affect the uptake of trypan blue by eosinophils incubated in assay medium for periods up to 36 hours (not shown). Similarly, the presence of INHIB did not affect the uptake of trypan blue by non-adherent eosinophils removed from cytotoxicity cultures. Furthermore, eosinophils incubated in medium with INHIB for 1 or 12 hours synthesized  $H_2O_2$  at the same rate as control incubated eosinophils, following stimulus with an optimal dose of phorbol myristate acetate (PMA).

In one experiment, for example, PMA increased the rate of  $H_2O_2$  production by a factor 63.5 and 66.3 for eosinophils incubated 12 hours with and without an optimal dose of INHIB, while the increase was by a factor of only 30.3 after a 5 minute preincubation with 0.01% sodium azide.

#### Effect Of Cytokine

The inventors also investigated the question of the effects of INHIB as specific for TNF stimulation of eosinophils or whether INHIB would also suppress the function of GM-CSF-stimulated eosinophils. Selected control sera (#s 51, 52, 53, and 54 from the Red Cross collection, see Table 2) and various control HPLC sizing fractions (not shown) had no effect on the cytotoxic function of GM-CSF-stimulated eosinophils. On the other hand, NR serum, chromatographically-purified INHIB from NR serum, and selected samples with

-38-

detectable INHIB (#s 25, 33, 41, and 67) all reduced by the cytotoxic function of GM-CSF-stimulated eosinophils (Table 2).

-39-

TABLE TWOEffect of INHIB on the Cytotoxic Function of  
TNF and GM-CSF-stimulated EosinophilsCytokine Stimulation of Eosinophils

<u>Inhibitor</u>	None	100 U/ml TNF	20 pM GM-CSF
None	9(a)	48	100
10% NR serum	23	24	33
20% INHIB (b)	13	27	46
Red Cross serum # (c):			
51	7	37	92
52	11	46	70
53	6	51	89
54	12	35	83
25	7	7	22
33	10	11	25
41	12	17	25
67	15	12	36

(a) the % maximum killing of schistosomula assayed at 36 to 40 hours, mean of duplicate cultures.

(b) derived from NR serum, dilution factor relative to the serum = 50.

(c) samples 51 through 54 were selected for the absence of an inhibitory activity; samples 25, 33, 41 and 67 were selected for the presence of inhibitory activity (see Fig. 7).

-40-

INHIB did not protect L929 cells from the toxic effects of TNF either in the presence or absence of actinomycin D, when added to the culture after various times of incubation. In contrast, the TNF-specific monoclonal antibody 245-10E11, protected the L929 cells when added early in the culture period (Fig. 11).

The inhibitory effect of NR serum or INHIB on the cytotoxic function of TNF-stimulated eosinophils could be observed when they were added to the eosinophils as late as 4 hours after the TNF. Monoclonal antibody 245-10E11 also inhibited TNF-enhanced cytotoxic function, but only when it was added simultaneously with the TNF to the eosinophils.

The effect of INHIB was observed when it was present for the first 2 hours of culture. When it was removed by washing after shorter durations of culture, the effects were diminished or undetectable. Preincubation of eosinophils with INHIB for up to 12 hours at 37°C and removal of INHIB by washing did not reduce the subsequent cytotoxic function of TNF-stimulated eosinophils.

#### USES FOR PURIFIED INHIB

Purified INHIB can be employed as a therapeutic agent in immunologic disease in mammals, particularly diseases in which suppression of inflammation would be helpful. For example, purified INHIB may be employed for the treatment of cancers, viral and other infectious diseases, autoimmune diseases, for the correction of immune-deficiency diseases, and the like. Purified INHIB could be used to generate antibodies as described, and to predict the structure of oligonucleotide probes; these reagents could be used to screen cDNA libraries for the isolation of the gene encoding INHIB. The purification method, or some of its components, could be used on a

-41-

larger scale for the purification of biosynthetic (recombinant) INHIB.

Understanding the processes by which INHIB inhibits cytokine-activated leukocyte immunologic activity, such as eosinophil cytotoxicity and neutrophil adherence, will aid in the development of its therapeutic and/or diagnostic uses in the fields of organ transplantation, allergy, and oncology, for example. This invention will enable those in the medical field to more effectively diagnose and treat inflammatory disease processes, and to utilize a quantitative assay for INHIB in order to monitor the time-course and/or intensity of ongoing clinical episodes of inflammation. The invention will further enable researchers to investigate mechanisms of eosinophil and neutrophil interactions with other cells and eosinophil and neutrophil function in inflammation.

While the invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modifications. This application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice within the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth as follows in the scope of the appended claims.

-42-

WHAT IS CLAIMED IS:

1. INHIB, capable of inhibiting the immunologic activity of an activated leukocyte, substantially free of natural contaminants.
2. The INHIB molecule of claim 1, wherein said molecule is a fragment of INHIB which is capable of inhibiting the immunologic activity of an activated leukocyte.
3. The INHIB molecule of claims 1 or 2, wherein said molecule is capable of inhibiting the cytotoxic function of an activated eosinophil.
4. The INHIB molecule of claims 1 or 2, wherein said molecule is capable of inhibiting the adherent function of an activated neutrophil.
5. The INHIB molecule of claims 1, 2, 3, or 4, wherein said leukocyte is activated by a cytokine.
6. The INHIB molecule of claim 5, wherein said cytokine is selected from the group consisting of tumor necrosis factor (TNF), granulocyte-macrophage colony-stimulating factor (GMCSF), and eosinophil cytotoxic enhancing factor (ECEF).
7. The INHIB molecule of any one of claims 1 or 2, wherein said molecule is detectably labeled.
8. The INHIB molecule of claim 7, wherein said molecule is detectably labeled with a label selected from the group consisting of a radioisotope, an enzyme, a fluorescent label, a paramagnetic label, and a free radical label.

9. An antibody derived by using an immunogen comprising the INHIB factor of claim 1.

10. An antibody derived by using an immunogenic and immunospecific peptide fragment of the INHIB factor of claim 1.

11. An antibody according to claims 9 or 10 in labeled form.

12. A method of diagnosing the presence and location of inflammation in a mammalian subject suspected of having an inflammation which comprises:

(a) administering to said subject a composition containing a detectably labeled binding molecule capable of identifying INHIB; and

(b) detecting said binding molecule.

13. A method of diagnosing the presence and location of an inflammation in a mammalian subject suspected of having an inflammation which comprises:

(a) incubating a biological sample of said subject in the presence of a detectably labeled binding molecule capable of identifying INHIB; and

(b) detecting said binding molecule which is bound in said sample of said tissue.

14. A pharmaceutical composition useful for treating inflammation in a mammalian subject comprising an inflammatory-reducing amount of INHIB, and a pharmaceutically acceptable carrier.

-44-

15. A method of treating inflammation in a mammalian subject which comprises providing to said subject in need of such treatment the pharmaceutical composition of claim 14.

16. The method of claim 15, wherein said inflammation is a reaction of the specific defense system.

17. The method of claim 15, wherein said inflammation is a reaction of the non-specific defense system.

18. The method of claim 15, wherein said inflammation is a delayed type hypersensitivity reaction.

19. The method of claim 15, wherein said inflammation is a symptom of an autoimmune disease.

20. The method of claim 19, wherein said autoimmune disease is selected from the group consisting of:

- (a) Raynaud's syndrome;
- (b) autoimmune thyroiditis;
- (c) EAE;
- (d) multiple sclerosis;
- (e) rheumatoid arthritis; and
- (f) lupus erythematosus.

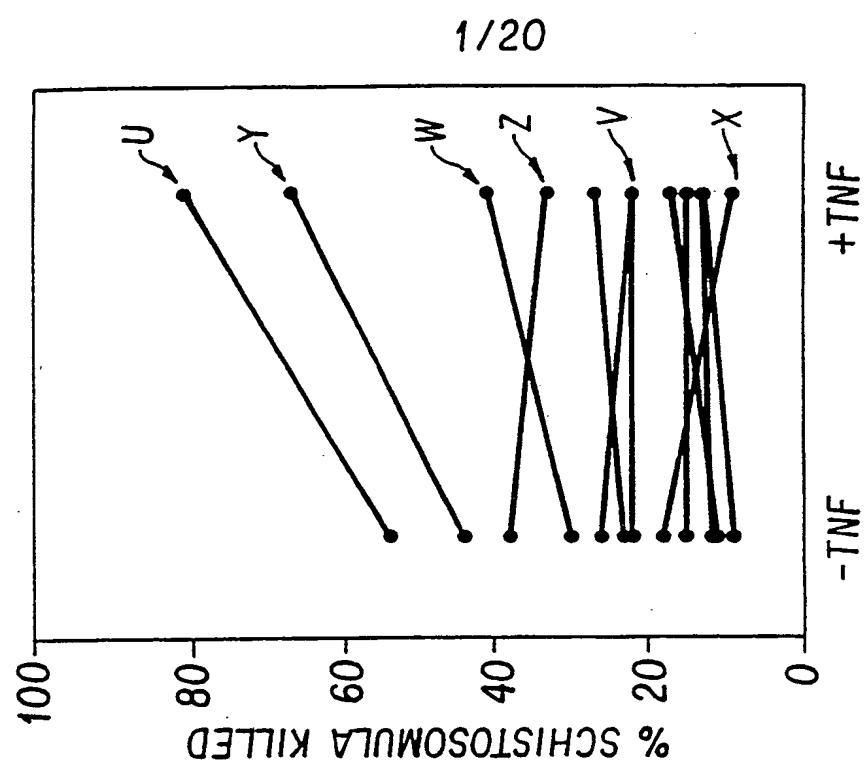


FIG. 1(B)

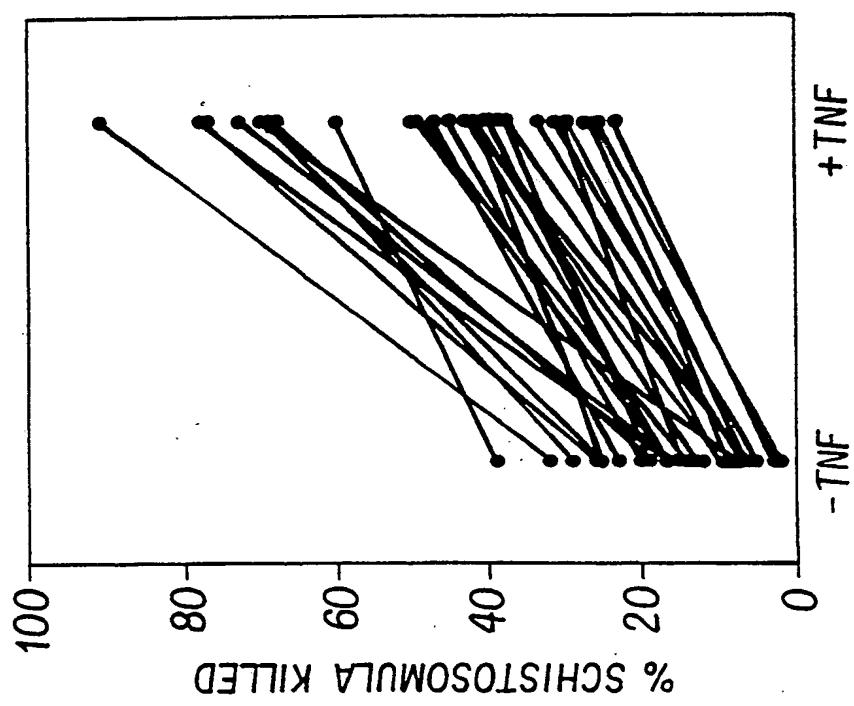


FIG. 1(A)

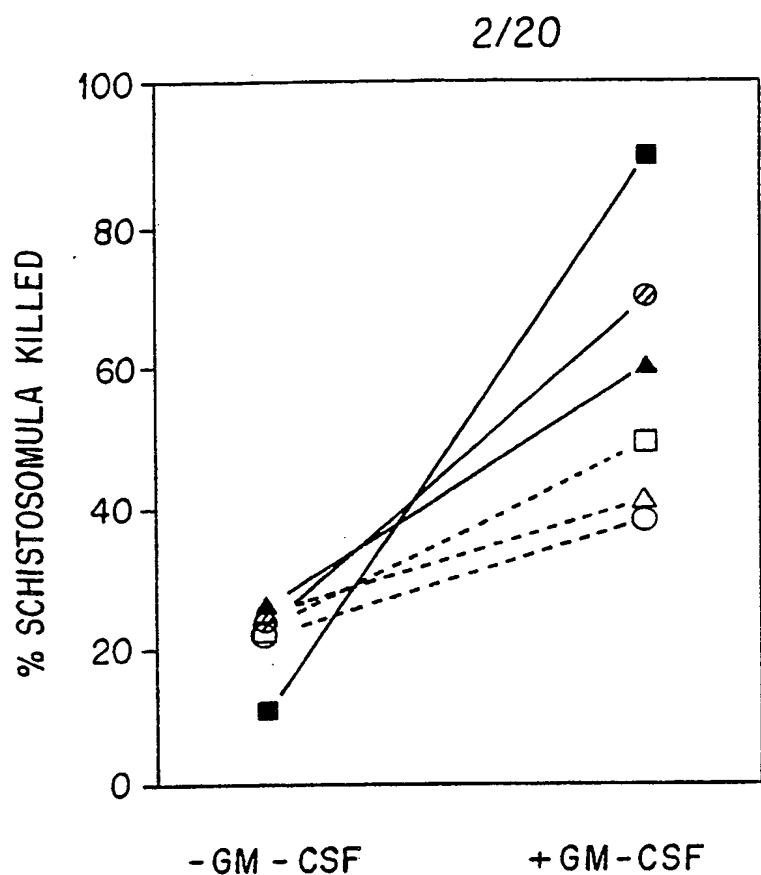


FIG. 2

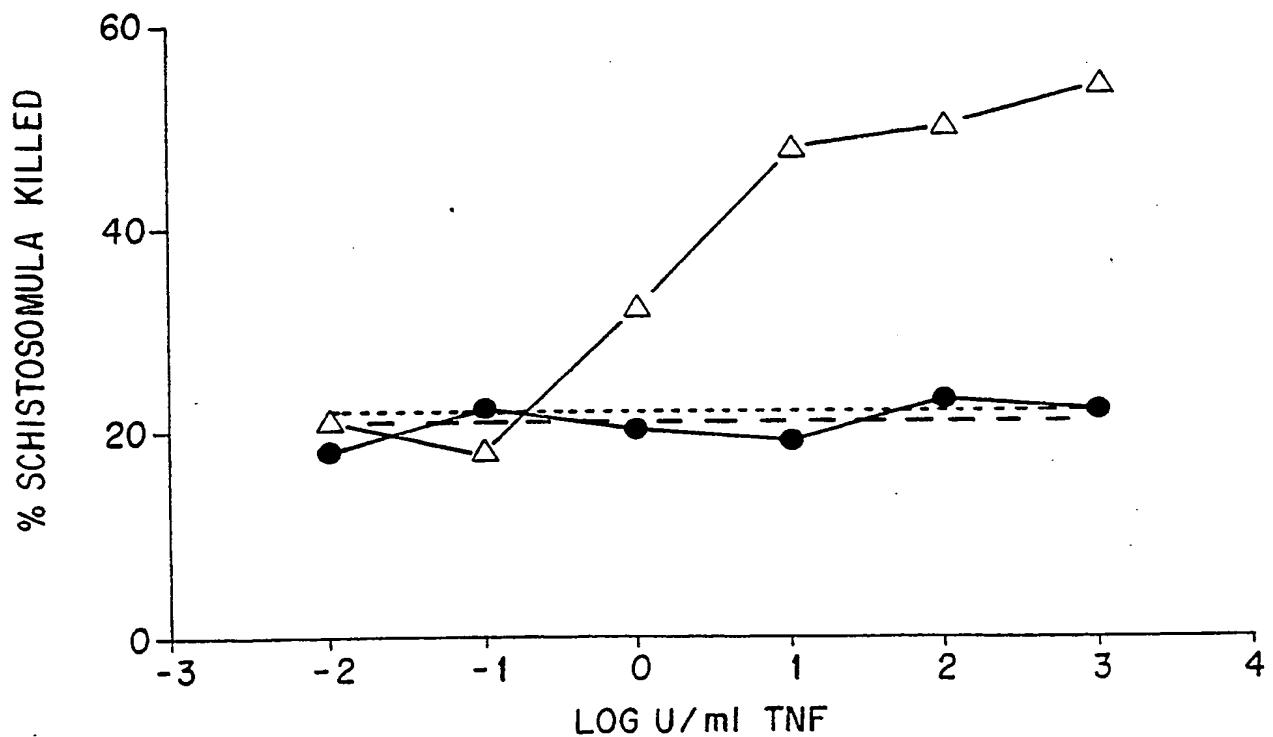


FIG. 1(C)

3/20

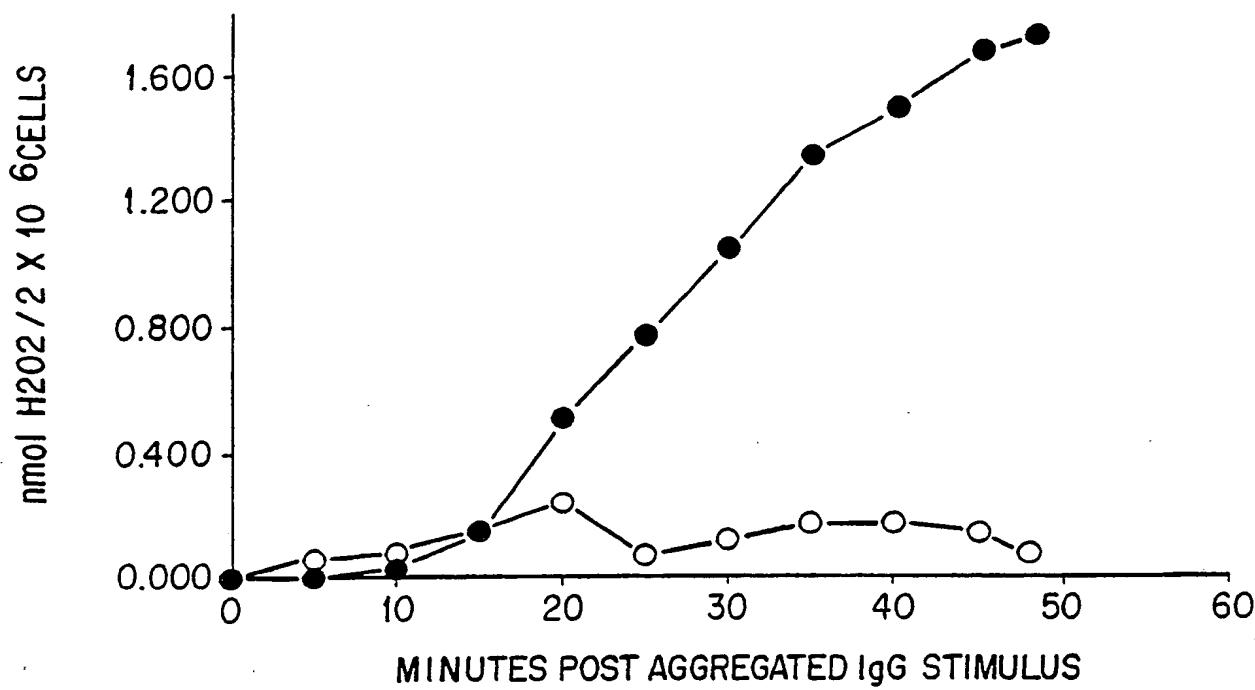


FIG. 3(A)

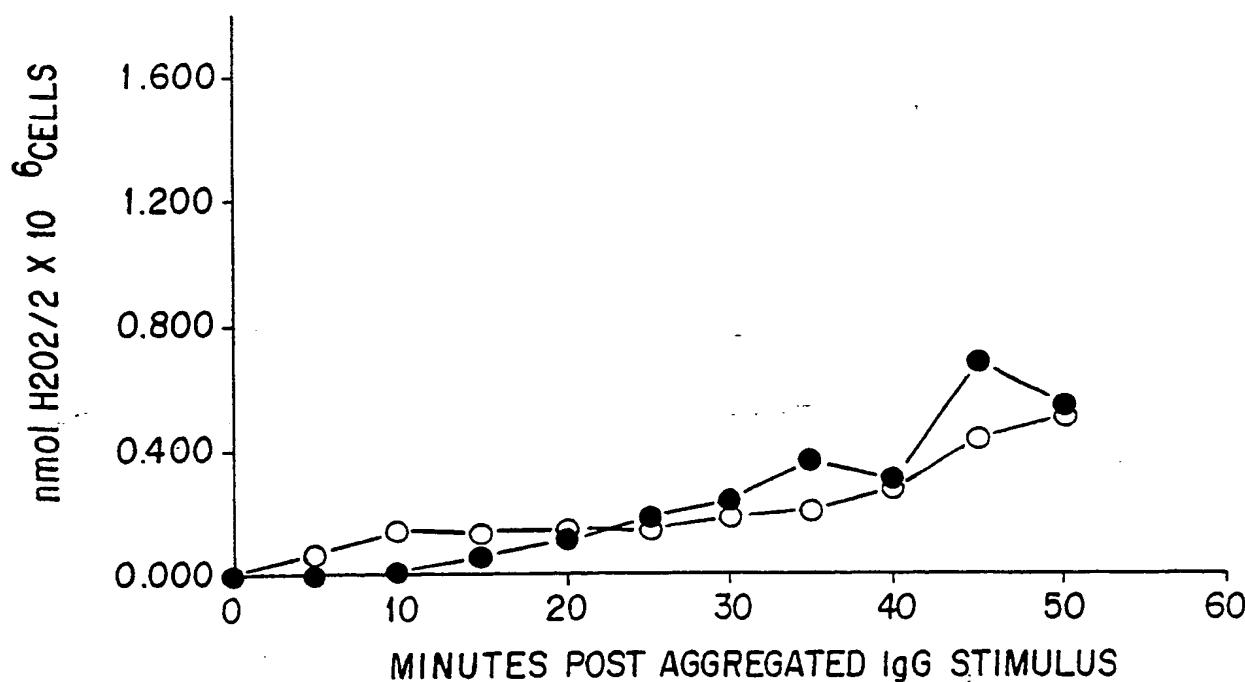


FIG. 3(B)

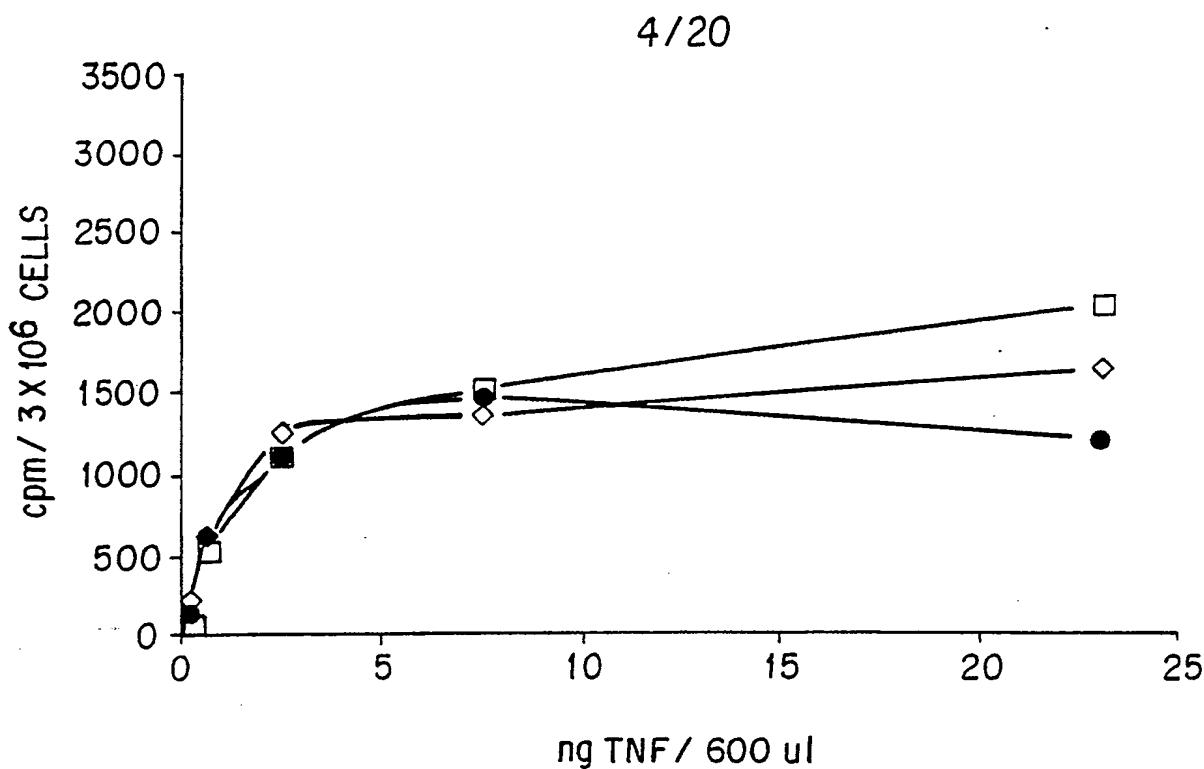


FIG. 4

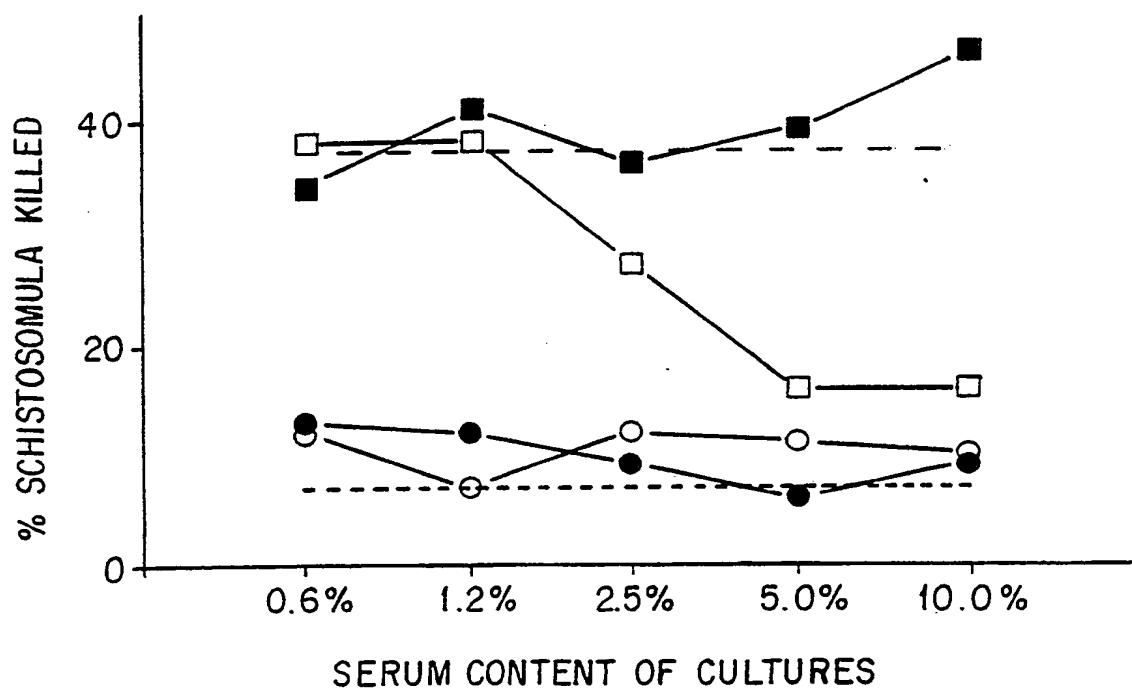


FIG. 5

SUBSTITUTE SHEET

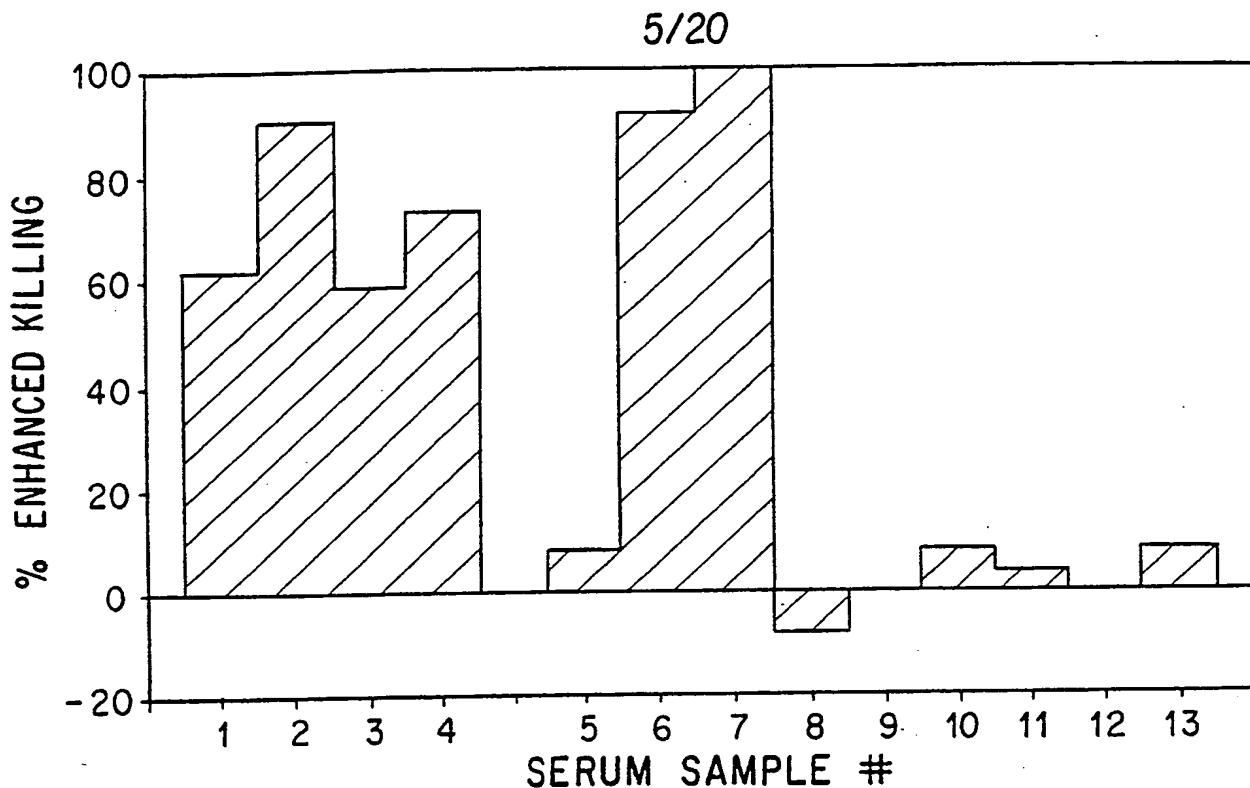


FIG. 6

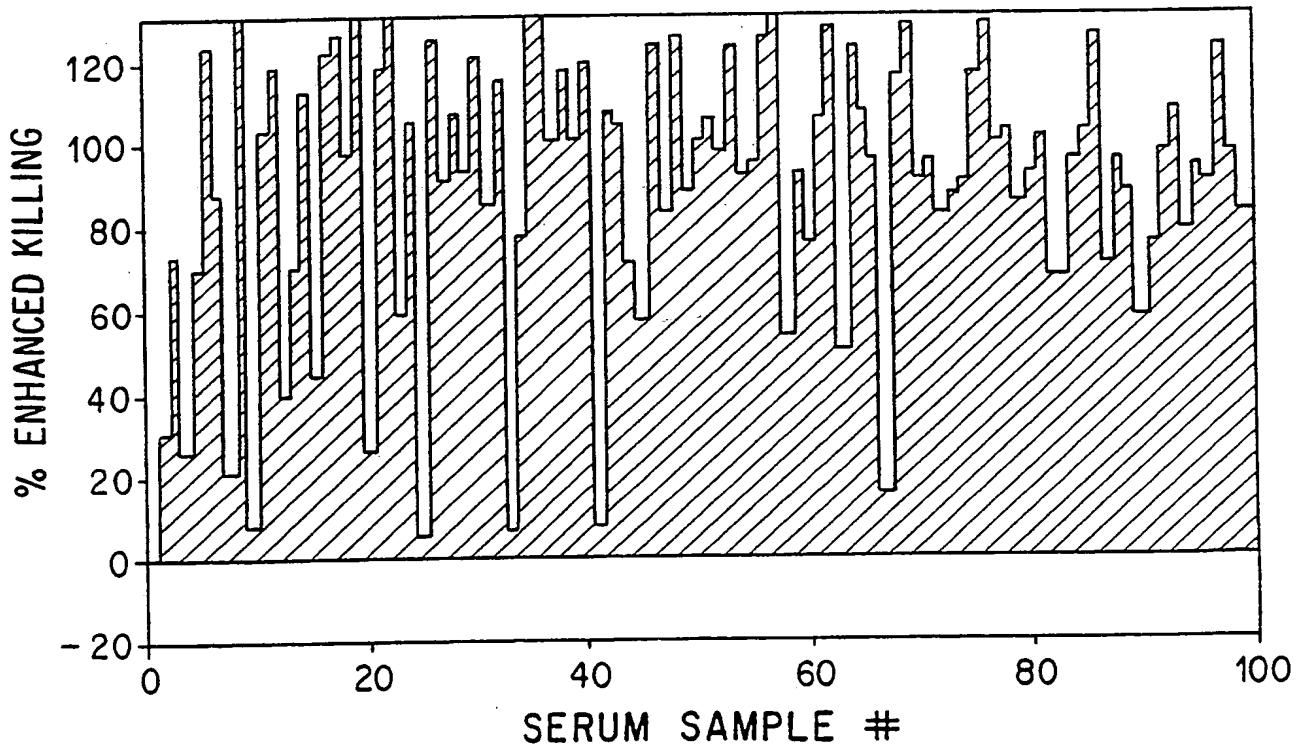


FIG. 7

6/20

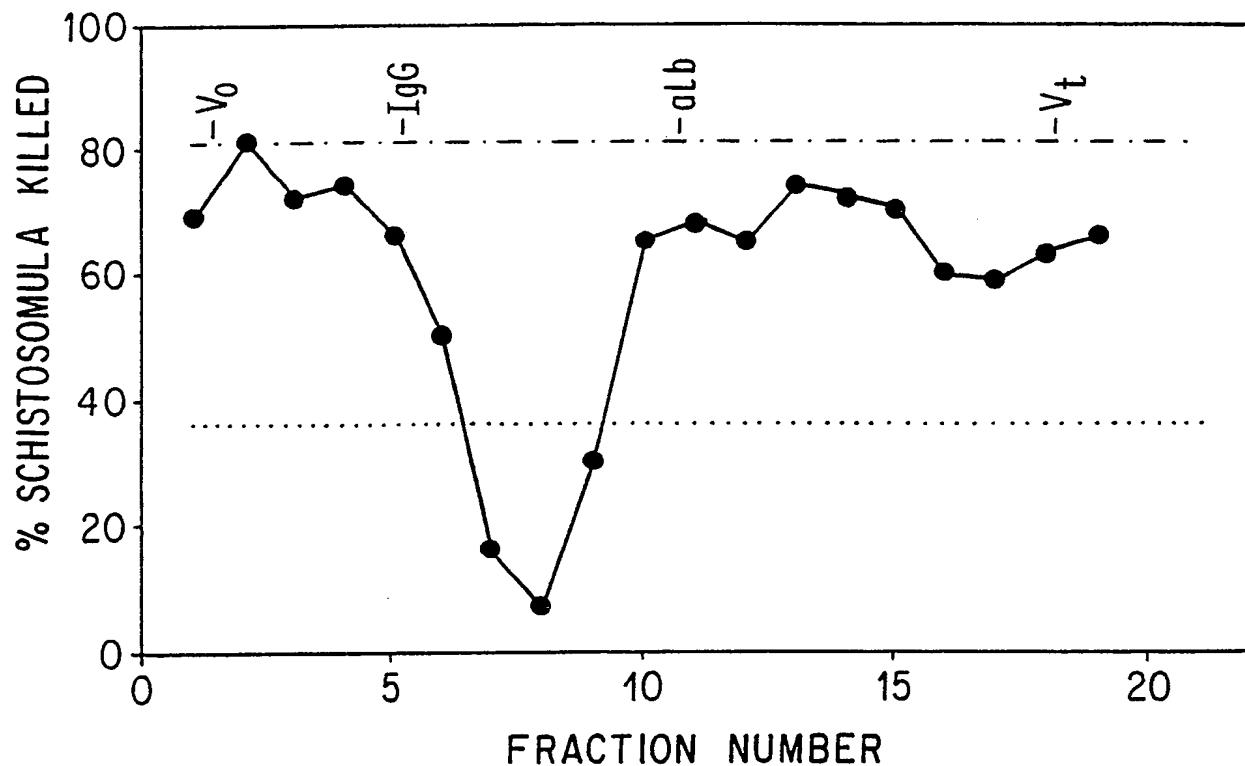


FIG. 8(A)

7/20

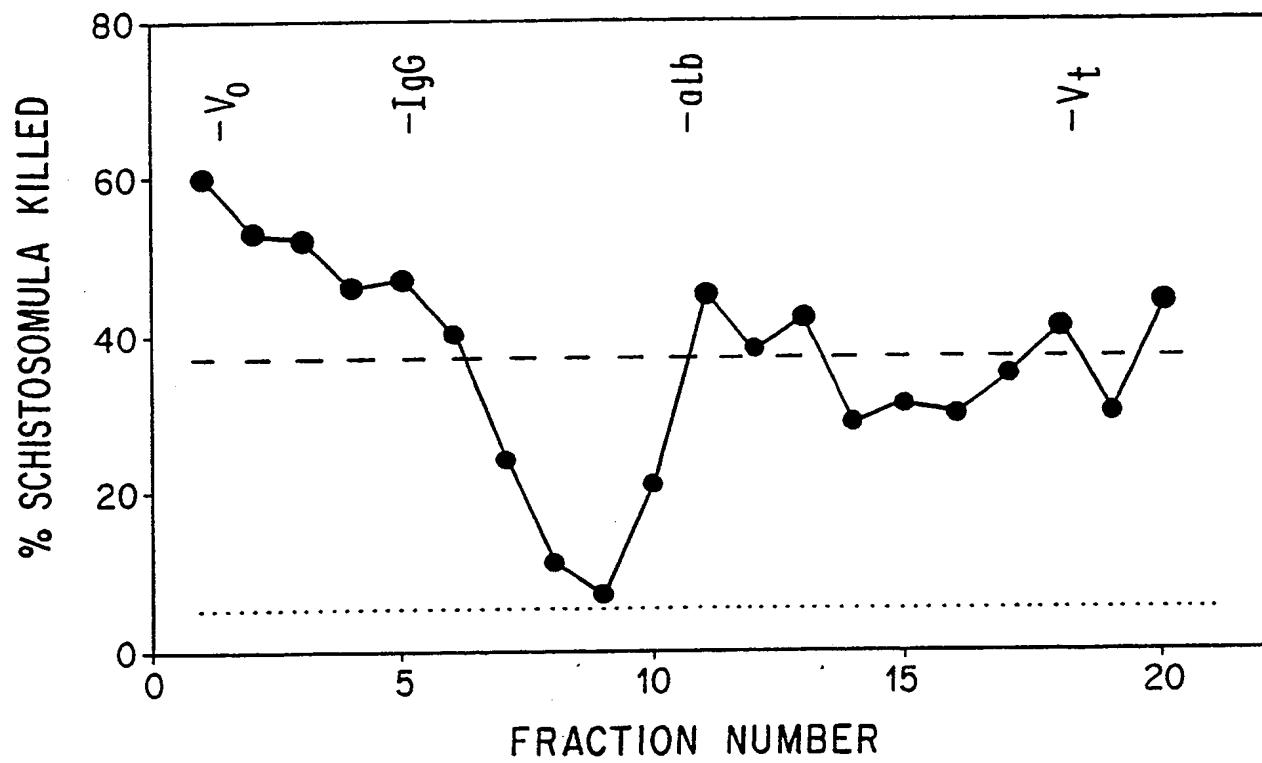


FIG. 8(B)

8/20

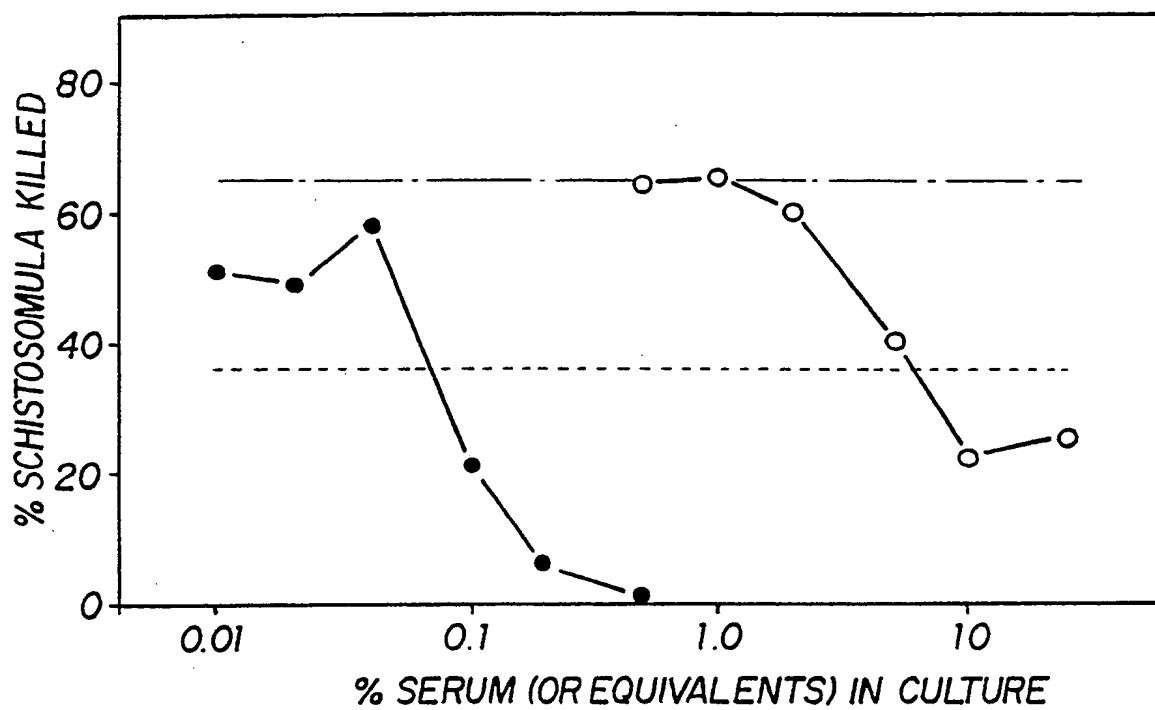


FIG. 9(A)

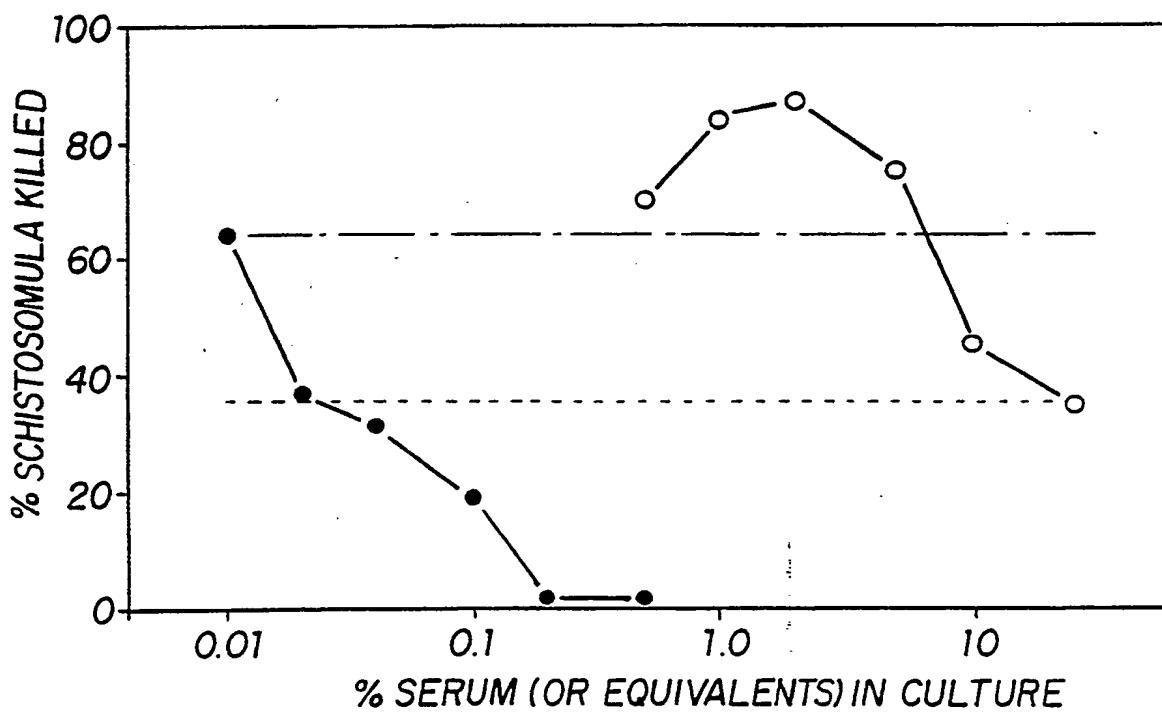


FIG. 9(B)

9/20

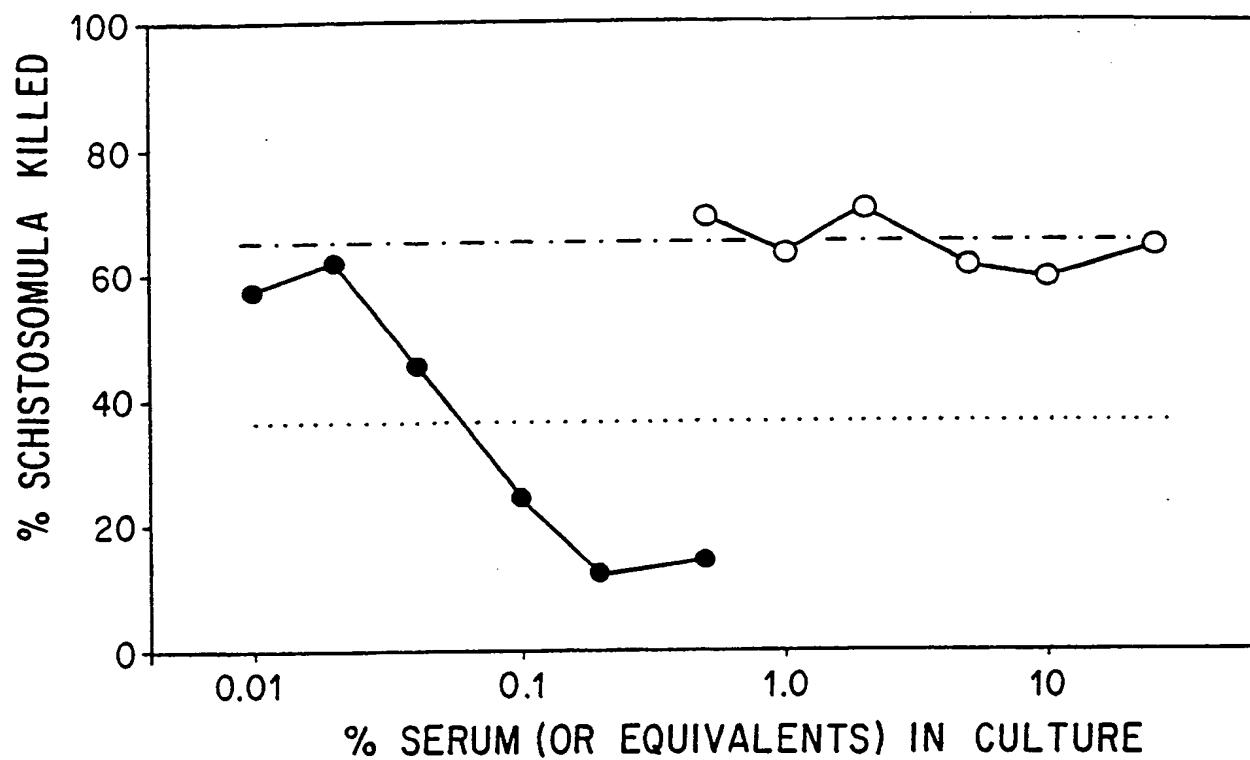


FIG. 9(C)

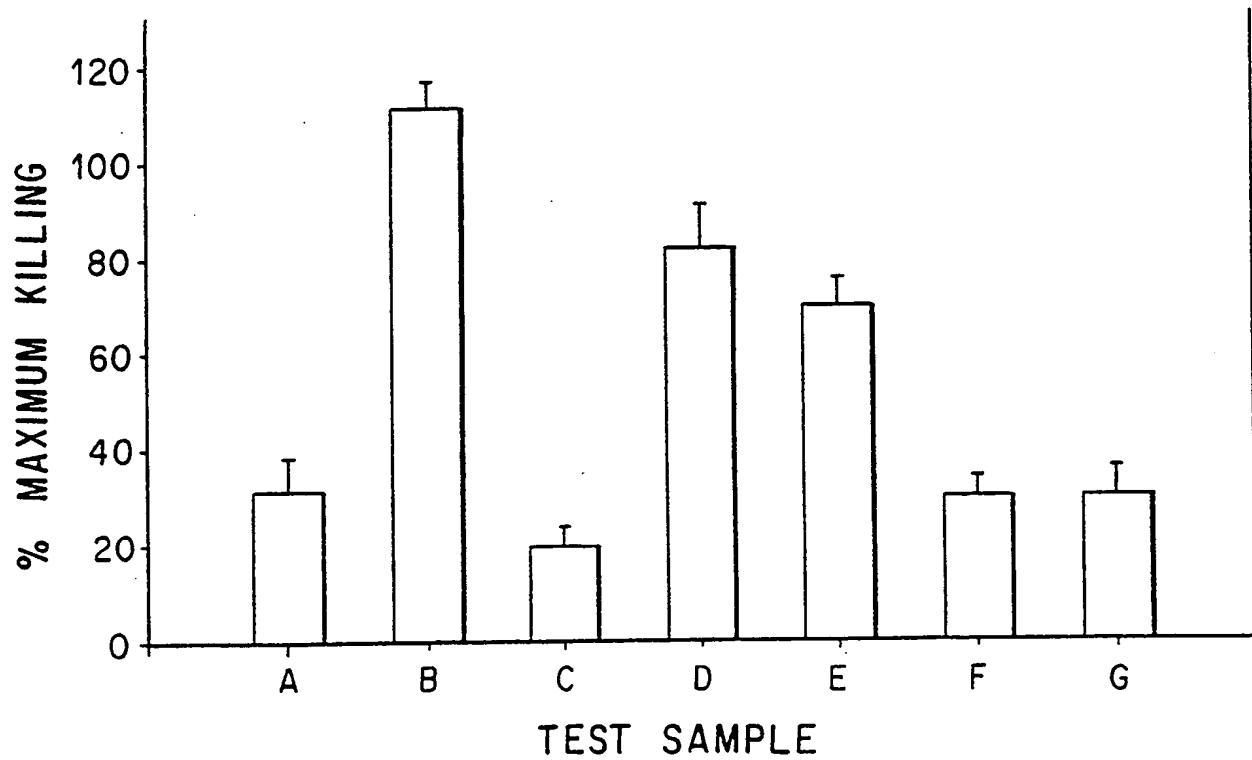


FIG. 10

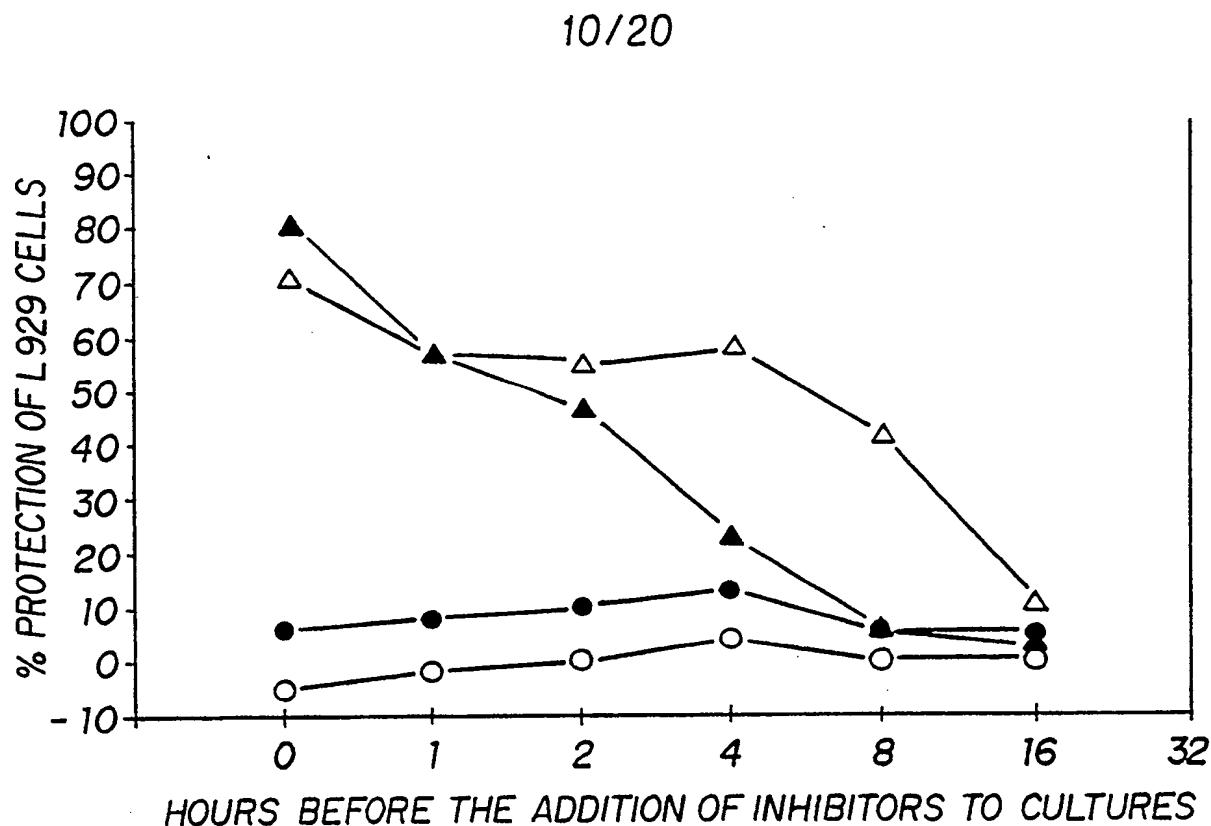


FIG. 11

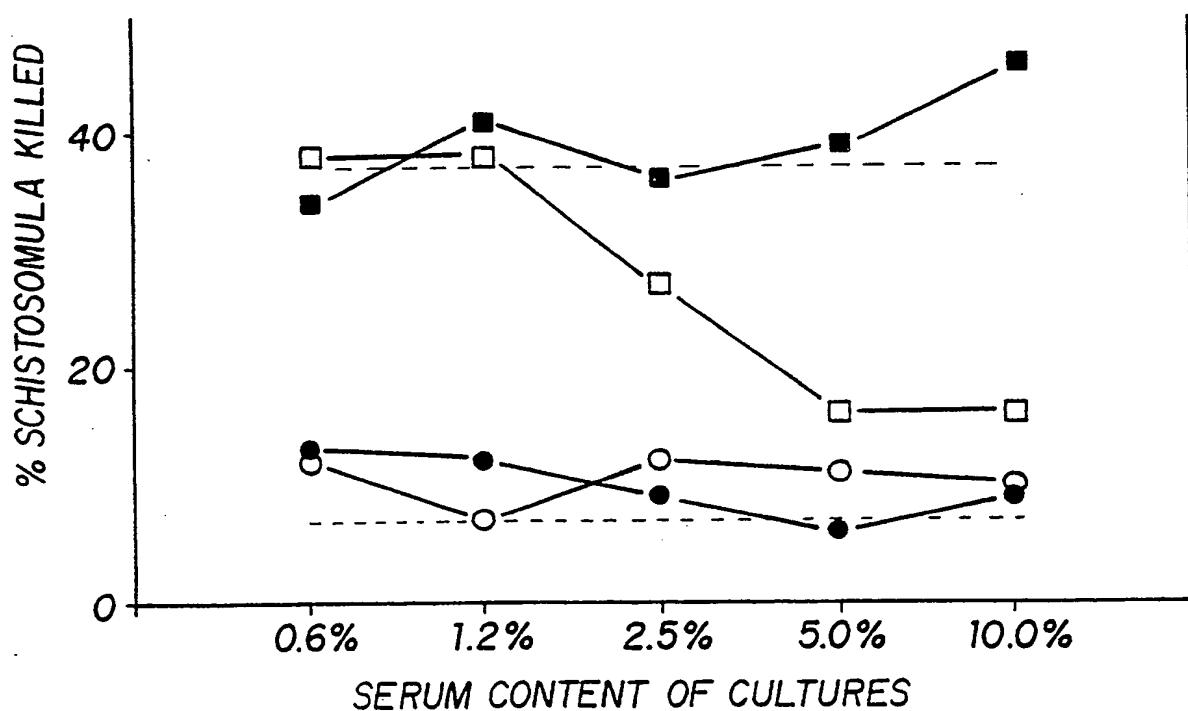


FIG. 12

11/20

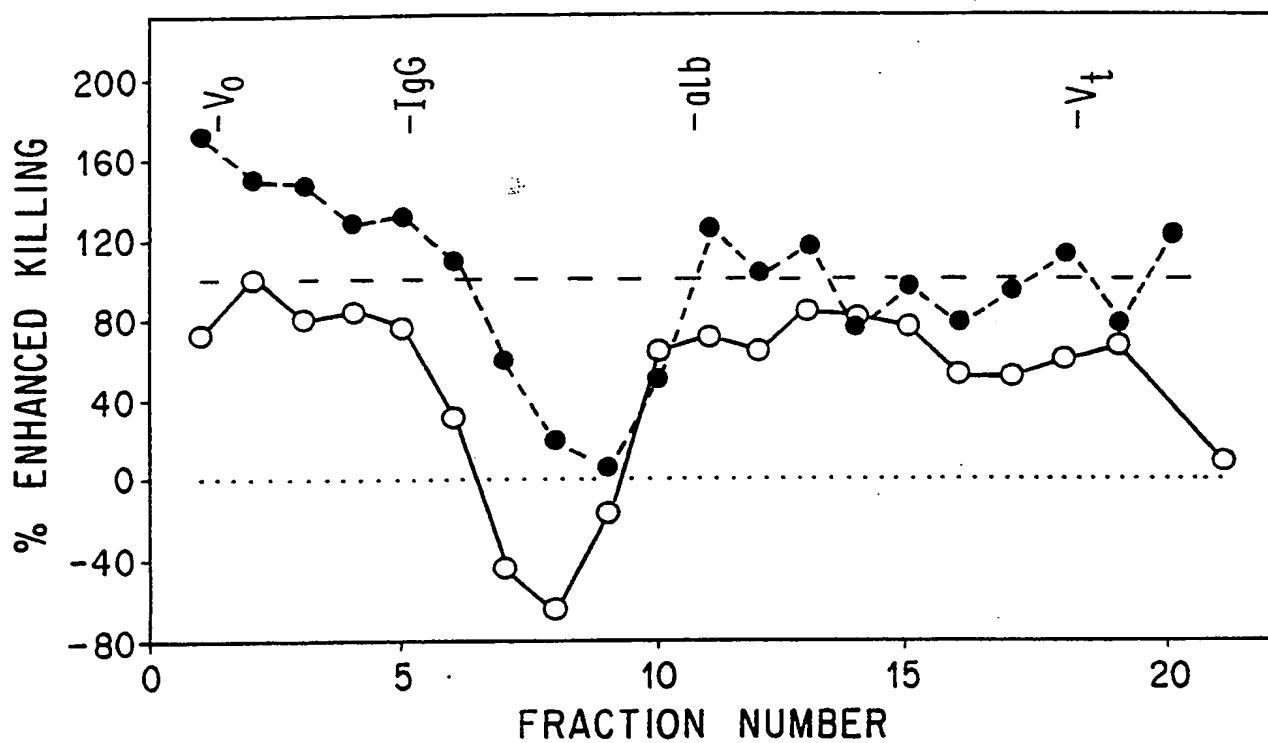


FIG. 13

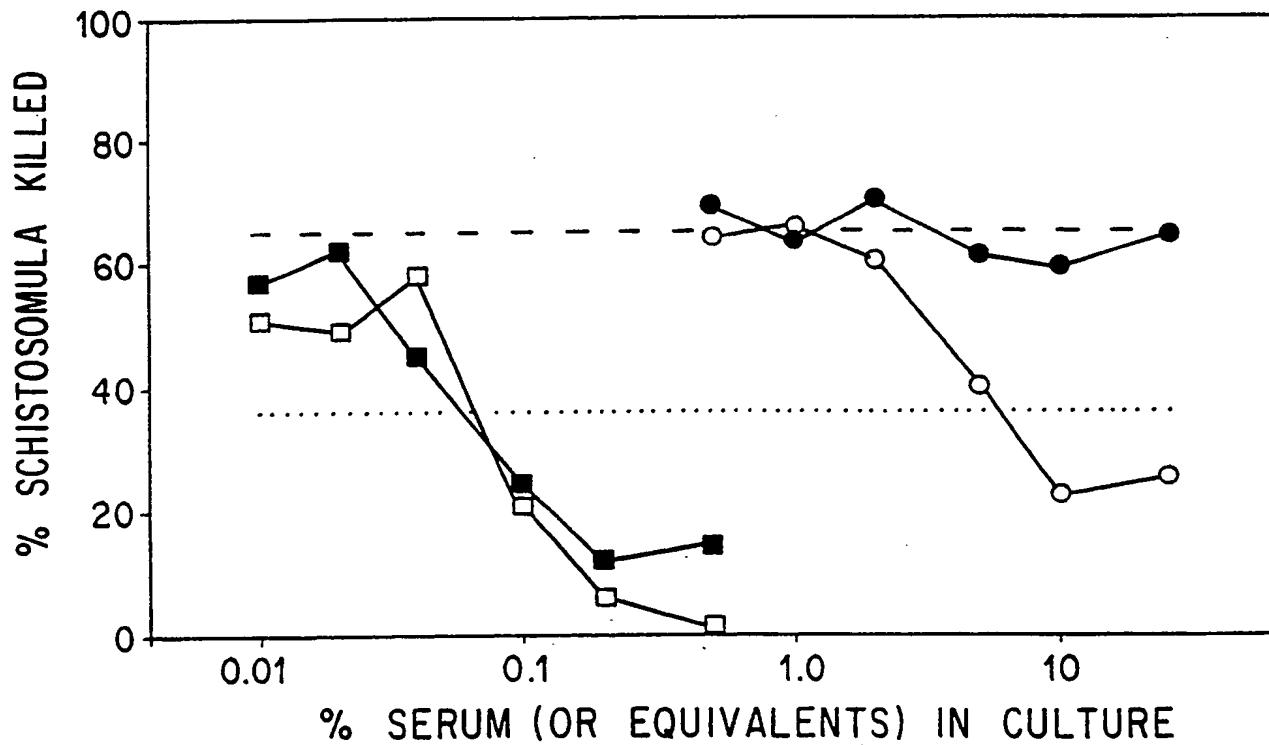


FIG. 14

12/20

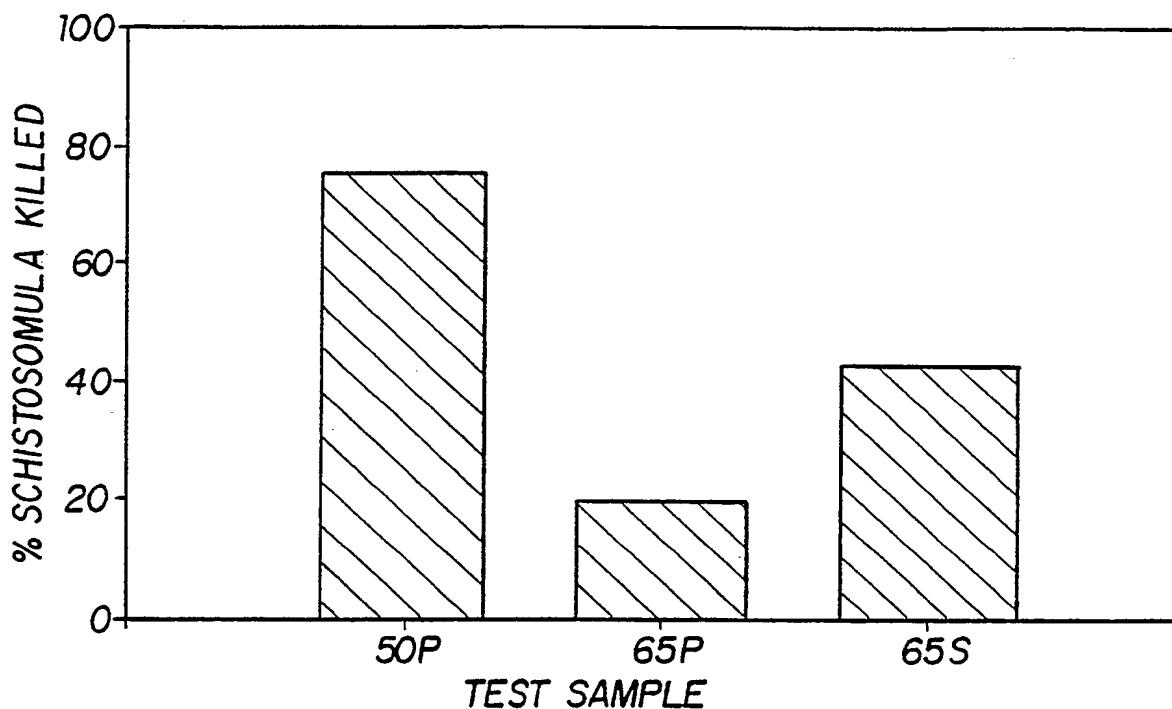


FIG. 15

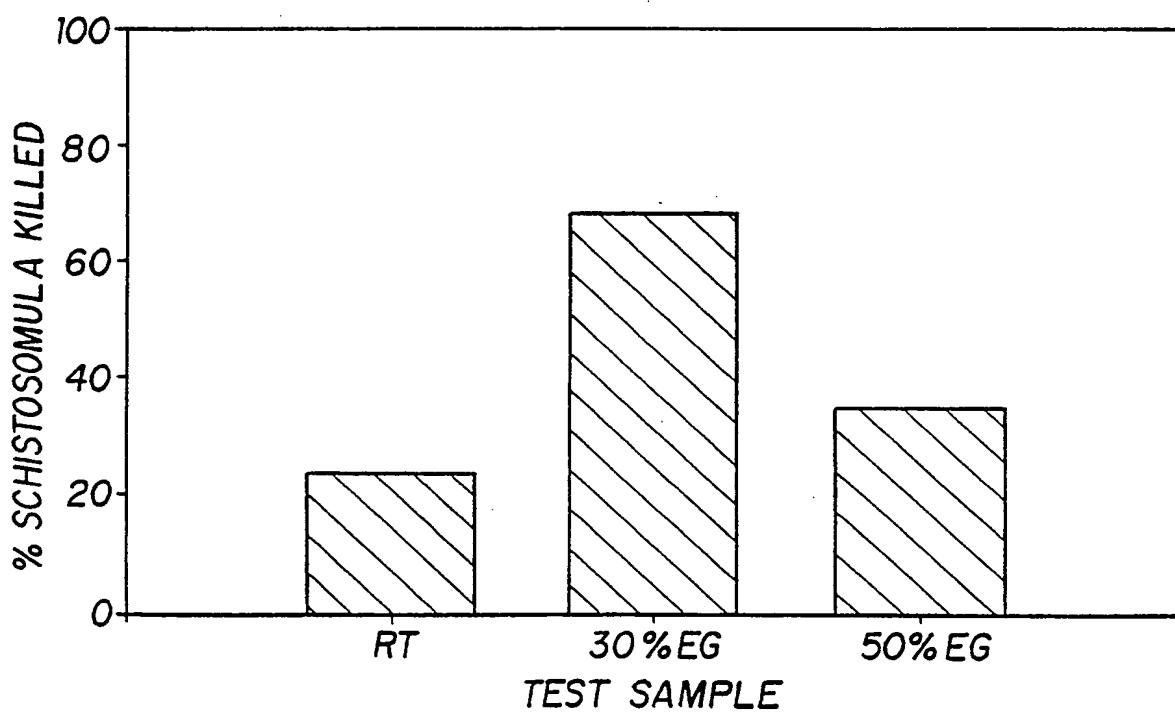


FIG. 16

SUBSTITUTE SHEET

13/20

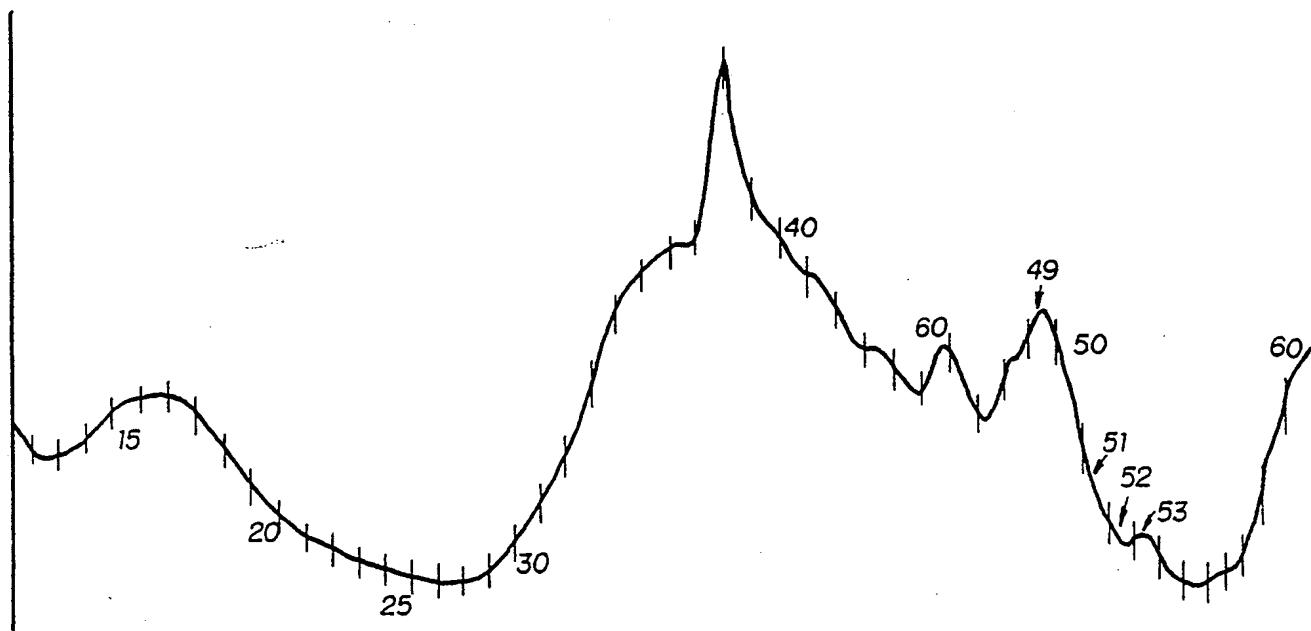


FIG. 17A

14/15

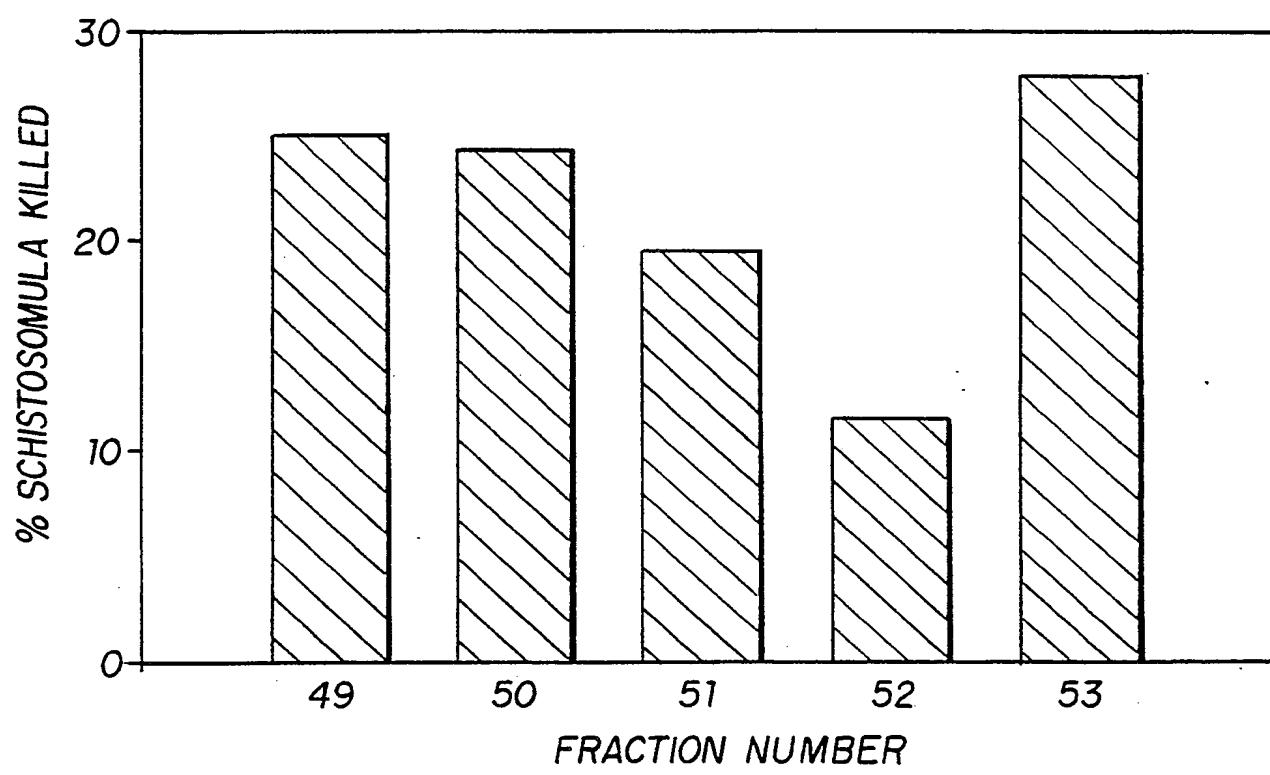


FIG. 17B

15/20

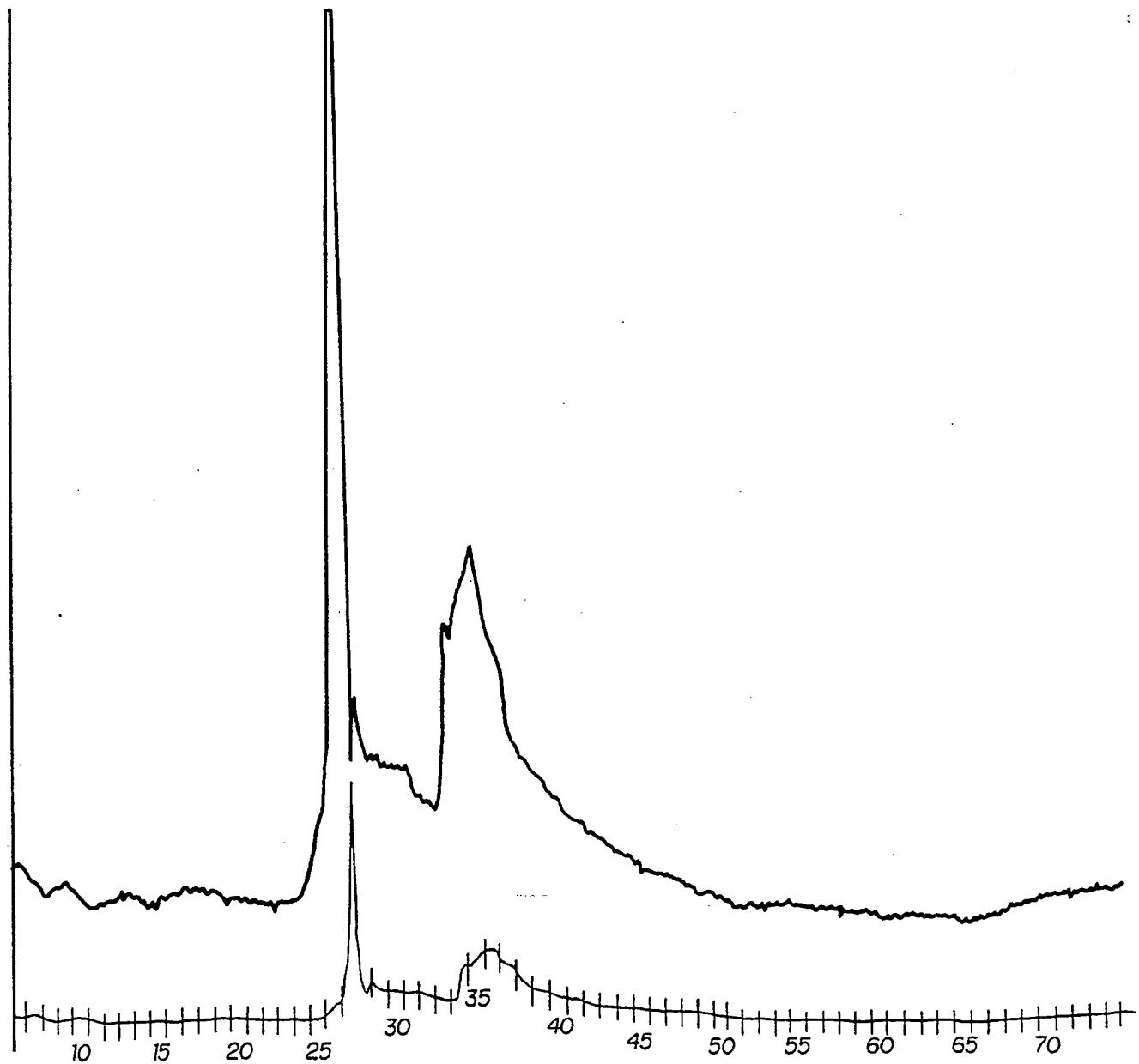


FIG. 18A

16/20

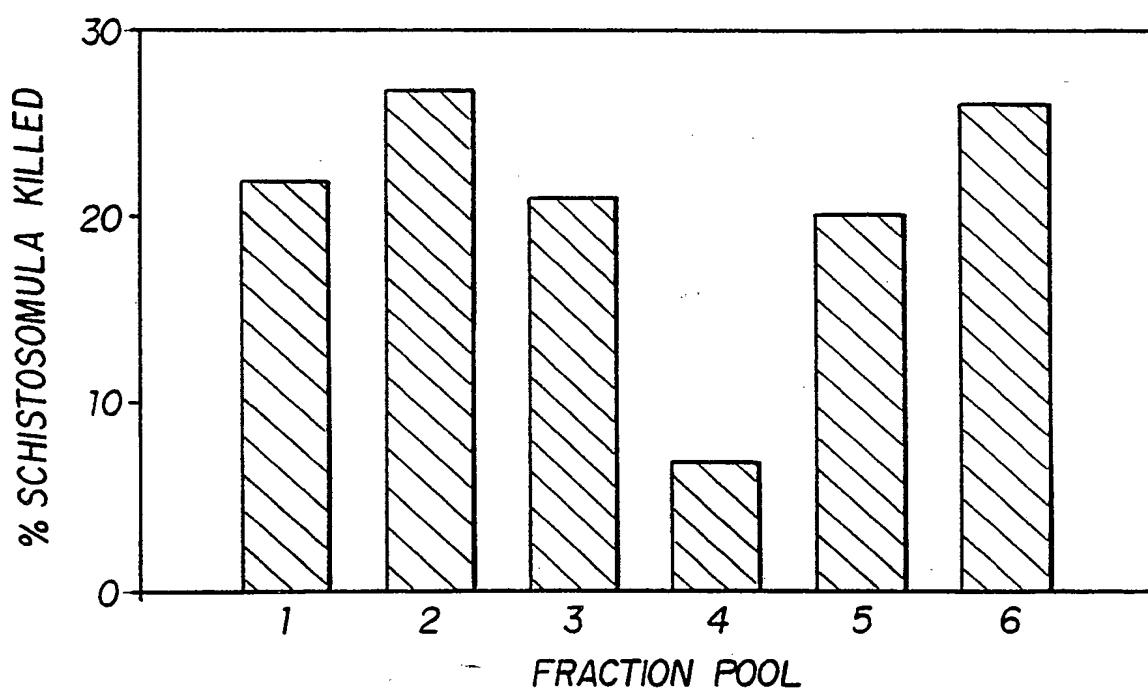


FIG. 18B

SUBSTITUTE SHEET

17/20

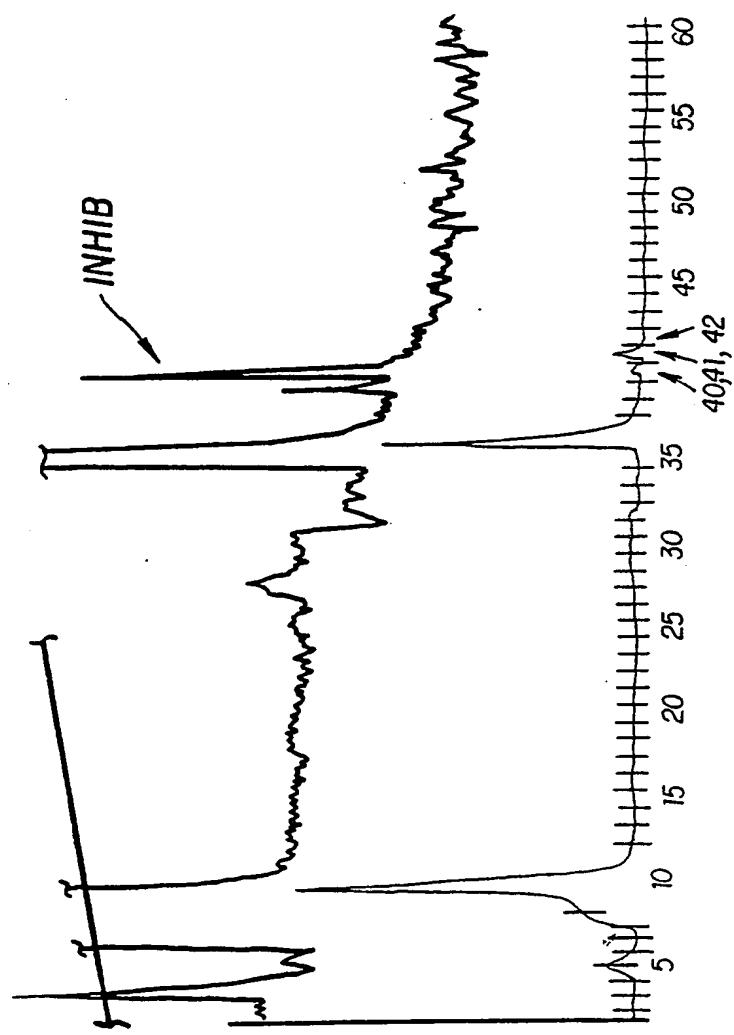


FIG. 19A

18/20

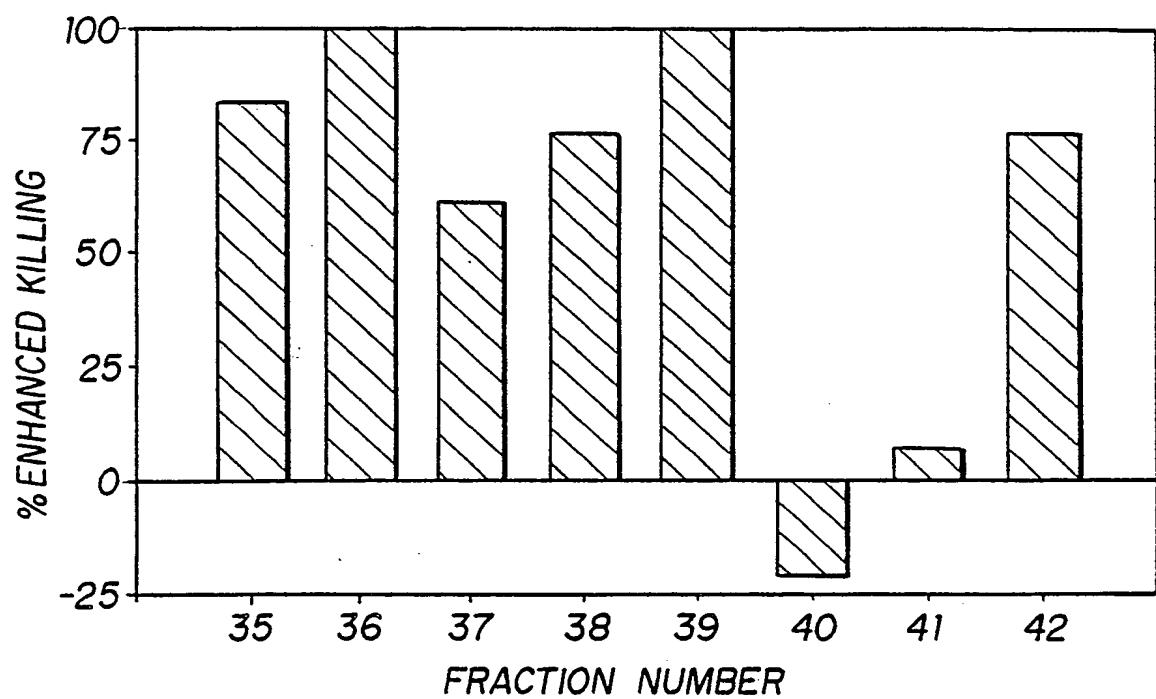


FIG. 19B

19/20

—Markers

40

INHIB

—Markers

FIG: 20

20/20

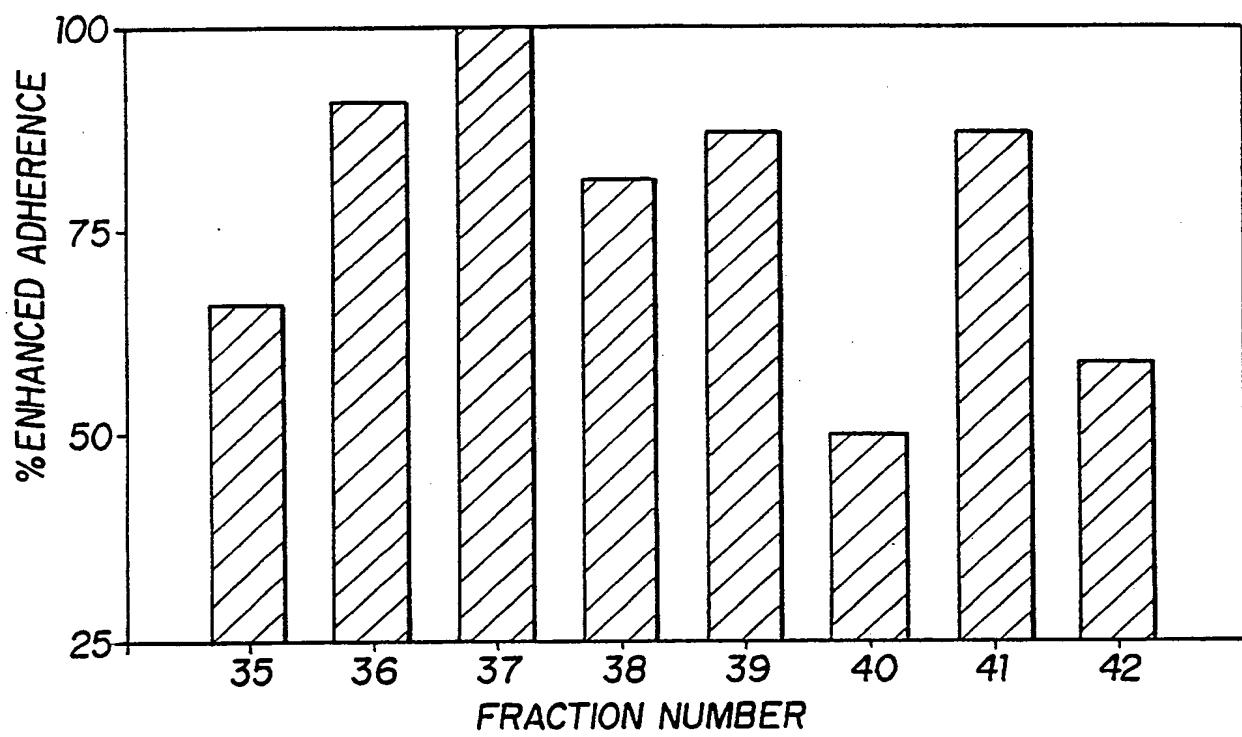


FIG. 21

# INTERNATIONAL SEARCH REPORT

International Application No. PCT/US89/04864

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) <sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC  
 IPC(5): A61K 39/00; GOIN 33/53; C12N 9/96; C07K 15/14 C12N 1/00  
 IIS Cl.: 424/9; 435/7,188; 436/547; 530/387; 935/110

## II. FIELDS SEARCHED

Minimum Documentation Searched <sup>7</sup>

Classification System	Classification Symbols
U.S.	424/ 1.1,9 ; 435/7,188, 172.2, 240.27; 436/501, 547; 530/300, 387; 935/107,110

Documentation Searched other than Minimum Documentation  
 to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>

Chemical Abstracts, Biological Abstracts and APS: Inhib? (P)  
 Tumor Necrosis Factor and neutrophil? or eosinophil?, inflamat?,  
 allergy, asthem.

## III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup>

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A, P	Chemical Abstracts, vol.111, 1989, Silberstein et al, "Human eosinophil cytotoxicity-enhancing factor. Purification, physical characteristics, and partial amino acid sequence of an active polypeptide", See Abstract No. 113461e. J. Immunol., vol. 143(3), 1989, p.979-83.	1-20
A, P	Chemical Abstract, vol.110, 1989, Silberstein et al, "Activation of eosinophils in cancer patients treated with IL-2 and IL-2 generated lymphokine- activated Killer cells", See Abstract No. 152536g, J. Immunol., 142(6), 1989, p. 2162-7.	1-20
A	The Journal of Immunology, vol. 140, 01 March 1988, Lamas et al, "Studies on the adhesive interaction between purified human eosinophils and cultured vascular endothelial cells", pages 1500-1505. See Abstract.	1-20

\* Special categories of cited documents: <sup>10</sup>

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

05 February 1990

Date of Mailing of this International Search Report

05 MAR 1991

International Searching Authority

ISA/US

Signature of Authorized Officer  
*Florina B. Hoffer*  
 Florina B. Hoffer

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V.  OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE<sup>1</sup>

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.  Claim numbers \_\_\_\_\_, because they relate to subject matter<sup>1,2</sup> not required to be searched by this Authority, namely:

2.  Claim numbers \_\_\_\_\_, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out<sup>1,3</sup>, specifically:

3.  Claim numbers \_\_\_\_\_, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI.  OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING<sup>2</sup>

This International Searching Authority found multiple inventions in this international application as follows:

See Attached Sheet

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application. **Telephone Practice**

2.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.  As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

- The additional search fees were accompanied by applicant's protest.
- No protest accompanied the payment of additional search fees.

## III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X Y	Immunology, vol. 63, 1988, Lin et al, "Inhibition of tumour necrosis factor and natural Cytotoxic cell lytic activities by a spleen cell-elaborated factor "pages 663-668. See Abstract and page 665, column 2, first full paragraph.	1-8 1-20
X Y	J. Exp. Med., Vol. 167, April 1988, Seckinger et al, "A human inhibitor of tumor necrosis factor ", pages 1511-1516. See Abstract and page 1516, lines 1-5.	1-8 1-20

PCT/US89/04864

Attachment of form PCT/ISA/210, PART VI.

I. Claims 1-11 and 13 are drawn to a INHIB polypeptide, a labeled INHIB molecule and an in vitro method of diagnosing the presence and location of inflammation, classified in classes 435, 436 and 530

II. Claims 12 and 14-20 are drawn to an in vivo method of diagnosing the presence and location of inflammation and a pharmaceutical composition useful for treating inflammation, classified in classes 424 and 514.

Reason for holding lack of unity of invention:

Group I is directed to a polypeptide and an in vitro diagnostic method, which product and method is materially different from the product and method of: Group II, which is directed to a pharmaceutical composition and an in vivo diagnostic method.

The search burden involved for each additional invention is undue, not only insofar as the additional parent search indicated by the separate classification, but also insofar as considerable additional literature searches covering the entire classes noted above.